STATE BOARD EXAMINATIONS

QUESTIONS AND ANSWERS

State Board Examinations

Questions and Answers

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Preface

The one thousand questions answered in this volume were carefully selected from the examination papers set by the State Boards of Examiners in Optometry. The book was compiled to meet the needs of those who may find it compulsory or advisable to take a State Board examination, and for optometry students generally.

The questions are probably more fully answered than a State examining board would expect, the idea being to give complete information on the special subject brought out by each question.

The contents are classified under different headings, which gives the work the character of a text-book and facilitates study and reference. As the questions were selected with a view to avoiding repetition, the book will be found to cover thoroughly every paper set by any of the State Examining Boards.

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Theoretic Optics

A coin one inch in diameter is held twelve inches from a lens which has a principal focus of four inches. Where will the image be formed and what will be its size? Show the calculation.

Parallel rays of light passing through this lens would be brought to focus at a distance of four inches. If the coin was placed at twelve inches the rays would be divergent and would reduce the power of the lens and throw the focus farther away. As these inch numbers must be expressed in fractions, the problem would be worked out by the usual formula, which in this case would be $\frac{1}{4} - 1/12 = 1/6$. So that the point where the image would be six inches from the lens and on the opposite side from the object.

Since the object is at a distance of twelve inches from the lens and the image at a distance of six inches from it, which is just one-half the distance, the size would be one-half the size of the object, or one-half inch.

Transpose into their plus and plus equivalents:

a + *1.50 D. sph.* ⊃ − *.37 D. cyl.* × *10°*
b + *5.00 D. sph.* ⊃ − *4.50 D. cyl.* × *150°*
c + *4.25 D. sph.* ⊃ − *1.75 D. cyl.* × *35°*

The rules that guide us are as follows:

The *sphere* is obtained by the algebraic addition of the sphere and cylinder.

The *cylinder* remains the same, but its sign and axis is changed.

Using these rules the results will be

a + 1.13 D. sph. ⊃ + .37 D. cyl. axis 100°
b + .50 D. sph. ⊃ + 4.50 D. cyl. axis 60°
c + 2.50 D. sph. ⊃ + 1.75 D. cyl. axis 125°

Transpose into sph. cyl. form:

a $+ 2.25$ *D. cyl.* $\times 10° \supset + 2.25$ *D. cyl.* $\times 100°$
b $- 1.75$ *D. cyl.* $\times 70° \supset + 3.00$ *D. cyl.* $\times 160°$
c $+ .75$ *D. cyl.* $\times 55° \supset - 1.75$ *D. cyl.* $\times 145°$

a. As this shows the same power in both meridians, and as these meridians are at right angles, the transposition would result not in a sphero-cylinder, but in a simple sphere of the same power. The answer is + 2.25 D. sphere.

b. The rules for the transposition of cross-cylinders are as follows:

1. Take either one of the cylinders for the *sphere.*
2. Take the algebraic difference for the *cylinder*, retaining the sign and axis of the cylinder that was not taken for the sphere.

Illustrate by three simple diagrams the law of reflection for a luminous point centrally placed before a plane, a convex and a concave mirror respectively.

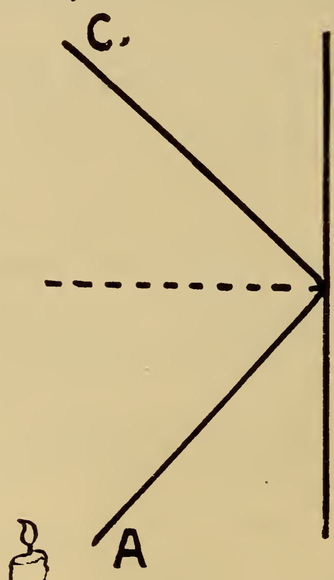

FIG. 1

The law of reflection is that the angle of reflection is the same as the angle of incidence. This law is illustrated in the preceding

diagram of a plane mirror where *A B* is the incident ray proceeding from the candle and *B C* the reflected ray.

The law of reflection is again illustrated in the second diagram, Fig. 2, representing a concave mirror where the parallel rays proceeding from *A* and *B* and striking *C* and *D* are reflected according to the law and meet at *F*.

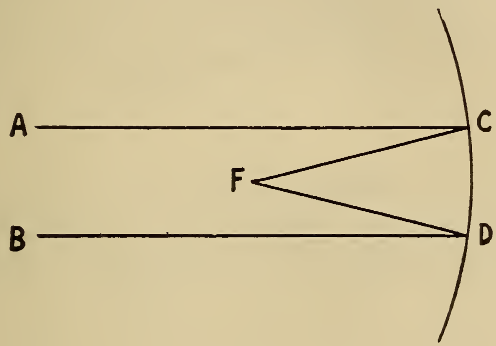

FIG. 2

The law of reflection is also illustrated in the third diagram, Fig. 3, representing a convex mirror, where the parallel rays proceeding from *A* and *B* and striking *C* and *D* are reflected according to the law and diverge as if coming from *F*.

Give the formula that defines the conjugate focal distances u and v for a spheric mirror, expressed in terms of the object distance u, the image distance v and the radius r.

The refractive power of a lens is inversely proportional to its focal length. For example if *F* represents the focal length *1/F* would represent the refractive power of a lens.

If u represents the distance of the object
If v represents the distance of the image
If f represents the distance of the principal focus
If r represents the radius of curvature,

then we have the formula

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \text{ or } \frac{2}{r}$$

If index is approximately 1.50, the focal length will be twice

the radius of curvature (2 r) for plano lenses, while in biconvex lenses the focal length is equal to the radius (F = r).

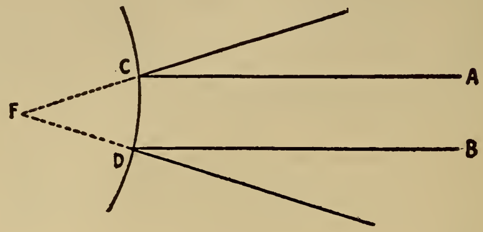

FIG. 3

When all of the distances, u of the object, v of the image and the radius of curvature r from the pole on the axis of a spheric mirror are counted positive in the direction opposite to light incidence, is the mirror convex or concave and is the image real or virtual?

In this diagram, Fig 4, the rays proceed from *B*, which is situated beyond the center of curvature *C*, and are focussed at *D*.

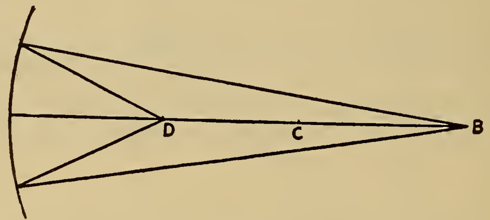

FIG. 4

These conditions correspond to those mentioned in the question and the mirror is concave and the image is real.

Give the value of the principal focal distance f of a spheric mirror, as deduced from the general formula for conjugate focal distances.

The formula is $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

If the distance of the object is 30 inches and the distance of the image is 10 inches, then the principal focus is 7½, which we get by substituting values as follows:

$$\frac{1}{30} + \frac{1}{10} = \frac{1}{7\frac{1}{2}}$$

Construct a diagram in which the linear dimensions of the object o and the image i are represented by lines perpendicular to the axis at a greater distance than the focus of a concave mirror and deduct therefrom the ratio of magnification expressed in terms of the focus f and the distance u of the object.

In this diagram, Fig. 5, $A\ V\ E$ is a concave mirror, $V\ X$ is the principal axis which passes through the center of curvature C and the principal focus F. $B\ D$ is a luminous object in front of the mirror at a distance $D\ V$ from the mirror.

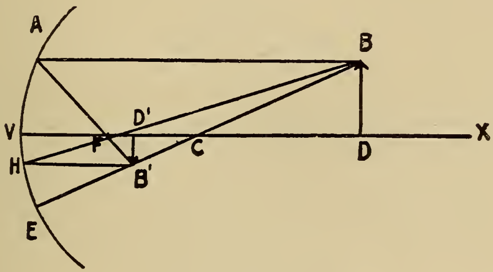

FIG. 5

One of the rays of light from the point B will pass through the center of curvature C and will strike the mirror at the point E. As it is incident in the same direction as a radius of curvature it is perpendicular to the arc of the circle and hence will be reflected back along the same line as it came.

Another ray of light from the point B, running parallel to the axis strikes the mirror at A and is reflected at such an angle as to pass through the principal focus F.

In its further progress it intersects the first-mentioned ray at B', which is, therefore, the image point of B. Consequently, $D'\ B'$ is a real and inverted image of $B\ D$ and it is apparent from the diagram that the image is smaller than the object.

The reverse of the above would also be true. Suppose $D'\ B'$ was the object a parallel ray $B'\ H$ after reflection would pass through F; and another ray from B' drawn through the center of curvature C would be reflected back upon itself and the two rays would intersect at B. Consequently $B\ D$ would be the magnified image of $D'\ B'$.

If i represents the image and o represents the object, the magnification or minification would be expressed by the fraction i/o.

The triangles $B\ D\ F$ and $V\ H\ F$ are similar and their corresponding sides are proportional.

$D'\ V$ is distance of object from mirror $= u$. $F\ V$ is distance of focus from mirror $= f$.

$D'\ B' =$ object $= o$

$B\ D =$ image $= i$

therefore

$$\frac{i}{o} = \frac{B\ D}{D'\ B'}$$

Also $$\frac{i}{o} = \frac{D\ F,}{F\ V} \text{ or } \frac{u - f}{f}$$

What is meant by the index of refraction?

The index of refraction is the numerical expression which indicates the refractivity of a medium as compared with air,

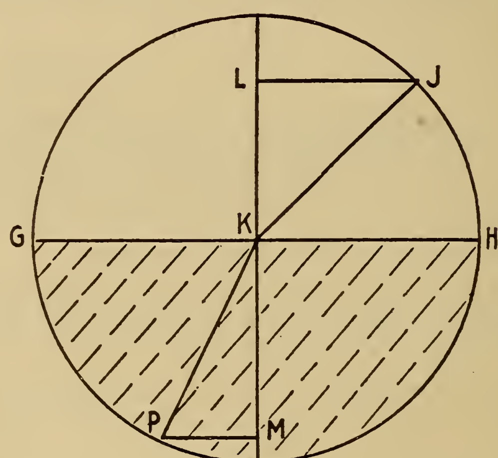

Fig. 6

which is taken as the standard or unit or 1, and hence every other medium being denser has an index greater than 1. The index of refraction depends upon the relation or ratio which constantly exists between the sine of the angle of incidence and the sine of the angle of refraction.

In order to illustrate the course of a ray of light as it passes from one medium to another of different density, Fig. 6, let *G H* represent a refracting surface separating air with an index of 1.00 from glass with an index of 1.50. Let *J K* be a ray incident on the surface of the point *K*, to which the line *L K M* is the normal or perpendicular; then *J K L* is the angle of incidence and *P K M* is the angle of refraction.

If we represent the angle of incidence by the letter *i* and the angle of refraction by the letter *r*, then the formula for ascertaining the index of refraction of any substance is expressed as follows:

$$\frac{\sin\ i}{\sin\ r} = \frac{L\ J}{P\ M}$$

If *L J* equals 3 and *P M* equals 2, then the first divided by the second equals 1.50 representing the index of refraction of the glass as compared with the standard taken or air.

Give the general formula that defines the conjugate focal distance u and v and for a convex refracting surface whose radius is r and whose refractive index is n, the object being at a distance u and the image at a distance v from the pole; also state in which direction from the pole the distances on the principal axis are counted positive or negative with respect to the direction of incidence.

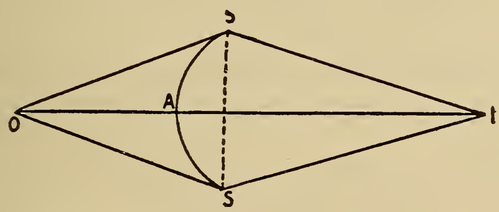

FIG. 7

In this figure, Fig. 7, the rays proceeding from the object *O* are converged after refraction and form the image *I*. Each is a real focus and the two are called conjugate foci. The convexity of the surface is turned toward the incident wave.

r = radius.

n = refractive index rarer medium.

n' = refractive index of denser medium.

u = distance of object.
v = distance of image.

$$\frac{n}{AO} + \frac{n'}{A\ I} = \frac{n' - n}{r}$$

Substituting u for $O\ A$ and V for $A\ I$ respectively we have

$$\frac{n}{u} + \frac{n}{v} = \frac{n' - n}{r}$$

This equation expresses the relation between the conjugate focal distance, $A\ O$ and $A\ I$. U is positive when measured in a direction opposite to the incident light and negative when measured in the other direction.

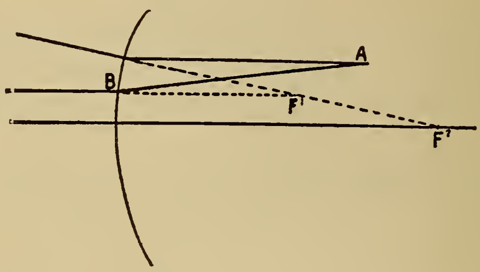

FIG. 8. (See opposite)

In the above formula which value must be given to u so as to obtain the second principal focal distance v, commonly designated as f_2?

If O is situated at such a distance that its rays are parallel, the distance $A\ O$ or u must be regarded as infinity and then n/u must equal zero.

Making this substitution in the foregoing equation we have

$$\frac{n'}{v} = \frac{n' - n}{r}$$

from which we derive the corresponding value of v or f_2.

$$V = \frac{u'\ r}{n' - n.}$$

What is the direction of the refracted ray with respect to the second principal focus when the incident ray is parallel to the axis of a spheric refracting surface?

From the formula given in the previous answer we ascertain the focusing point for rays that are parallel before refraction. The distance of this point from the surface is the *posterior or second principal focal distance* and is often denoted by the letter f_2, the value of which is derived from the equation just mentioned.

Show in a simple diagram, by means of the principal lines of direction, the positions of the first and second principal foci, F_1 and F_2, with respect to a luminous point slightly above the principal axis, nearer than the focus and located to the right and in front of a concave refracting surface.

Let A represent a luminous point, from which a parallel ray of light after refraction by the concave surface will diverge as if proceeding from the point f_2 which is the second principal focal distance. A divergent ray from A striking the concave refracting surface at B will after refraction be parallel to the axis and appear to proceed from the point F_1. (Figure 8, opposite.)

From the general formula for conjugate focal distances,

$$\frac{1}{v} - \frac{1}{u} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

for a thin lens having a radius of curvature r_1 for the first surface (exposed to incidence) and a radius r_2 for the second surface, give the value of the second principal focal distance f_2.

If u equals infinity, then

$$\frac{1}{v} \text{ or } \frac{1}{f^2} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

It being true that the first and second principal focal distances f_1 and f_2 for a thin lens are equal, give the equation from which the focal length f may be deducted.

If f be the focal length of a thin convex lens, then

$$\frac{1}{f} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Or if each surface has the same radius of curvature the formula may be written

$$\frac{1}{f} = (n - 1)\frac{2}{r}$$

What are the laws of refraction?

A ray of light striking a medium perpendicularly is not bent.

A ray of light striking a medium obliquely in passing from a rare to a denser medium is bent *toward* the perpendicular.

A ray of light striking a medium obliquely in passing from a dense to a rarer medium is bent *from* the perpendicular.

Define principal focus, ordinary focus and conjugate foci.

The principal focus is the focal point for parallel rays.

An ordinary focus is the meeting point for rays which diverge from some point inside of infinity and are brought together at some point beyond the principal focus.

Conjugate foci are interchangeable, so that the rays which diverge from one will always converge to the other.

What two factors determine the dioptric power of a lens?

Index of refraction and radius of curvature.

When light passes from a medium which is optically dense to one that is optically rare, what change in the direction of the light is there?

If the ray of light strikes the medium perpendicularly, it passes unchanged; if it strikes it obliquely it is bent away from the perpendicular.

What is the rule for figuring the radius of curvature of lenses, the index of refraction being given, and the focal power of the lens?

The radius of curvature divided by the index of refraction less unity, equals the focus of a plano-convex lens. Hence the index of refraction, less unity, multiplied by the focal power of the lens, equals the radius of curvature.

Suppose the index of refraction is 1.50 and the focal length of the lens 20 cm., then we have

(1.50 − 1) × 20 = 10 cm., which is the radius of curvature.

The focal length of a convex lens is 12 cm.; an object is placed 20 cm. in front of the lens. Where will the image be and will it be erect or inverted? Show the process of the figuring.

If the focal length of the convex lens is 12 cm., the refractive power of the lens is 8.33 D. The focal length of curve refers to parallel rays before entering the lens. If such rays are divergent the focus is thrown farther away, according to the degree of divergence.

If the rays proceed from a distance of 20 cm. they would have a divergence of 5 D., which must be subtracted from 8.33 D., leaving 3.33 D., which means a focal distance of 12 inches or 30 cm.

Or using the reciprocals we have the following equation:

$$\frac{1}{12} - \frac{1}{20} = \frac{1}{30}$$

Having a biconcave lens, it is found that using one surface as a mirror the image of a distant object is at 8 inches from the surface; while testing the other surface in the same way, the focus is 4 inches. What will be the power of the lens if the refractive index of the glass is 1.50?

Inasmuch as the principal focus of a mirror is one-half the radius, therefore an 8-inch focus would indicate a 16-inch radius, or a 2.50 D. value; and a 4-inch focus an 8-inch radius or 5 D. value.

Now the formula for focal distance is as follows:

$$\frac{1}{F} = (N - 1)\left(\frac{1}{-R_1} + \frac{1}{-R_2}\right)$$

or substituting values:

$$\frac{1}{F} = (1.50 - 1)\left(-\frac{1}{8} + -\frac{1}{16}\right)$$

or

$$\frac{1}{F} = (.50)\ (-\ 5D. + -\ 2.50\ D.)$$

or

$$\frac{1}{F} = -\ 3.75\ D.$$

At what distance will parallel rays be focused by a concave mirror whose radius of curvature is 17 inches?

The principal focus of a concave mirror is always equal to half the radius of curvature; therefore, in this case, parallel rays will be focused at 8½ inches.

What is the radius of curvature of a plus 1.50 lens, crown glass?

The index of refraction is not mentioned; it may vary from 1.48 to 1.56 or even 1.60, but for sake of illustration we will say it is 1.50.

Then we have focus multiplied by index less unity equals radius of curvature, or substituting figures

$$26 \times (1.50 - 1) = 13$$

Therefore, 13 inches is the radius of curvature if the lens is plano, as proved by the rule that the focal length of a plano-convex lens is equal to twice the length of its radius.

If the lens is biconvex we have

$$26 \times 2\ (1.50 - 1) = 26$$

Here 26 inches is the radius of curvature as proving the rule that the focal length of a biconvex lens is equal to its radius.

What radius of curvature must be ground on the two surfaces of a periscopic lens, one of the surfaces to be on a radius of 5 cm., the total dioptric power to be 8 D., and the refractive index to be 1.50? How is it worked out? In inches or millimeters?

If the radius of curvature of one surface is 5 cm. then according to the rule that the focal length is twice the radius, the focal length of this surface is 10 cm. which means that the value of this surface is + 10 D.

Now then, if the total power of the lens is + 8 D., the opposite must show a − 2 D. curve, or 20 inches. If according to the rule this is twice the length of the radius, the latter must be 10 inches.

If the index had been other than 1.50 the results would have been slightly different.

If a point of light is at a distance of 16 inches from a + 4.50 D. lens, where will the light be focussed?

The rays diverging from a point of light at a distance of 16 inches will require + 2.50 power to overcome this divergence and make them parallel. This leaves + 2 power of the + 4.50 D. lens to act on these parallel rays, which will be brought to a focus at 20 inches.

A 2 D. lens decentered 5 mm. will produce how much prismatic action?

According to the standard there is 1° prismatic power developed for every 1 D. of refractive power with a decentration of 10 mm., and ½° for every 1 D. lens with a decentration of 5 mm.

The question asks how much prismatic action. We do not know whether the framer of the question had in mind prismatic power or deviation, but to cover both phases the answer would be as follows: 1° of prismatic power and as the angle of deviation is one-half the principal angle, ½° of deviation.

Object is 10 inches high and its distance from the mirror is 40 inches; the image formed by the mirror is 5 inches distant; what is the height of the image?

The height of the image bears the same relation to the height of the object as the distance of the image bears to the distance of the object.

Let x represent height of image which it is desired to find and using the known values we have

$$x : 10 :: 5 : 40$$

$$\text{or } x = \frac{10 \times 5}{40} = \frac{50}{40} = 1\tfrac{1}{4}$$

Object is 80 inches from a mirror; its image is 20 inches from mirror and is 2 inches high. How high is the object?

The same proportion holds good as in previous question. Using x for the unknown quantity and substituting the values as given we have

$$20 : 80 :: 2 : x$$

Then

$$x = \frac{80 \times 2}{20} = \frac{160}{20} = \frac{8}{1}$$

Or $x = 8$ inches, which is the height of the object.

The object is 24 inches wide and its image is 3 inches wide. The distance of the object from the mirror is 32 inches; what is the distance of the image?

The width of the object bears the same relation to the width of the image as the distance of the object bears the distance of the image.

The first three values are given and the fourth or the unknown will be represented by x, and then we have the following proportion:

$$24 : 3 :: 32 : x$$

Then

$$x = \frac{32 \times 3}{24} = \frac{96}{24} = \frac{4}{1}$$

Or x = 4 inches, which will be the distance of the image.

Let the image be 2 inches high and the object 20 inches high; let the distance of the image be 4 inches; what will be the distance of the object from the mirror?

The size of the image is to the distance of the image as the size of the object is to the distance of the object, which may be expressed as follows:

$$2 \text{ in.} : 4 \text{ in.} :: 20 : x$$

Then

$$x = \frac{4 \times 20}{2} = \frac{80}{2} = 40 \text{ inches}$$

which is the distance of the object.

In the preceding example what will be the power of the mirror if it is convex?

The general formula for mirrors is as follows:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{F}$$

It must be borne in mind that the formula for a convex mirror is the same as that for a concave mirror, but in working with these formulae it is necessary to remember that in the case of the convex mirror v is always a negative quantity, because the focus of a convex mirror is not real but virtual.

Hence the formula would be

$$\frac{1}{u} + -\frac{1}{v} = -\frac{1}{F}$$

or substituting the values given in the previous question,

1 D. + − 10 D. = − 9 D.

which is the negative focus or power of the convex mirror.

Solve the same problem by the formula, but the mirror to be concave.

Here the quantities are all positive, and using the values given in the previous question expressed in diopters, we have

1 D. + 10 D. = + 11 D.

as the positive focus or power of the concave mirror.

A ray of light is incident on a plane surface at an angle of 60° with the normal; the refracted ray forms an angle with the normal of 45°. The sine of 45° is 0.707, and the sine of the angle 60° is 0.866; how is the index of refraction found and what is it in this particular case?

To find the index of refraction of any substance as compared with air, it is necessary to divide the sine of the angle of incidence by the sine of the angle of refraction. In this case we divide the sine of the angle of incidence (0.866) by the sine of the angle of refraction (0.707) and the result of 1.225 approximately as the index of refraction in this case.

What is the relation of size of image to object as compared with the distance of these from a lens, and is there any difference in the rule with a convex and a concave lens?

The size of the image is to the size of the object, as the distance of the image is to the distance of the object. This applies to both convex and concave lenses, and when any three of these values are known the fourth can be figured out.

What effect has obliquity on the image of a point of light, such as an illumined pinhole in a sheet of black paper when formed by a thin convex lens?

The production of a more or less irregular blur in place of a true point image. There is an increase in the refractive power of all meridians of the lens, but especially so in the meridian at right angles to the axis of rotation, thus developing the effect of a stronger sphere with the addition of a cylindrical element.

The focus of a concave mirror is 20 inches; where will be the image of an object placed at the following distances from the mirror: 20 inches, 40 inches, infinity?

If an object be placed at 20 inches from a 20-inch concave mirror; in other words if the object be placed at the focal distance of a concave mirror its image will be at infinity.

If the object be placed at 40 inches the mirror must first overcome the divergence of rays proceeding from this distance, leaving a sufficient convergence to bring the rays to a focus at 40 inches.

If the object was placed at infinity the image would be formed at the focal distance of the lens, which is 20 inches.

Where must an object be placed to obtain a real image four times the size of the object, using a + 2.50 D. lens?

If image and object are at the same distance from the lens they will be of the same size and the image will increase in size

in proportion to its distance. Therefore in order to obtain a real image four times the size of the object its distance must be increased four times.

In this case the lens is a + 2.50 D. with a focal distance of 16 inches of which one-fifth will represent distance of image and four-fifths distance of the object. This is 1/80 and 1/20 respectively, or 80 inches for the distance of the image and 20 inches for distance of object. This is proven to be correct by the transposition of these inch numbers into diopters 80 inches = .50 D. and 20 inches = 2 D., the sum of which is 2.50 D., the number of the lens given in the question.

How is the curvature of a spherical wave of light measured? How would you verify the fact that when a spherical wave of light passes directly through a thin lens the change in the curvature of the wave is the same for all positions of the lens?

The curvature of the wave front is inversely proportional to the distance of its source, and hence the curvature of a spherical wave of light is measured by the reciprocal of that distance. If a one meter length of radius be taken as the unit, the curvature of the wave front at a distance of one meter is said to be 1 D. At half a meter it is 2 D., at one-third meter 3 D., and at two meters .50 D.

Parallel rays of light or a plane wave, passing through a 1 D. lens, will be given a curvature of 1 D., and so on.

In order to prove that the change in curvature of a spherical wave in passing through a thin lens is constant, we fall back upon the regular formula for conjugate foci:

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$

in which o represents the distance of the object, i the distance of the image and f the principal focus.

$\frac{1}{o}$ expresses the curvature of the wave diverging from the object and meeting the lens, $\frac{1}{i}$ the curvature of those leaving the lens to form the image and $\frac{1}{f}$ the focal length of the lens. The latter must be a constant and if $\frac{1}{o}$ is increased or diminished, $\frac{1}{i}$ must be decreased or increased in the same ratio.

If the curve of a biconvex lens on one surface is on a radius of 13½ inches and on the other on a 40-inch radius, what is the power of the lens?

Such a lens is equivalent to one plano-convex lens with a radius of 3 D. and another plano-convex lens of 1 D. radius. Now, then, the focal length of a plano-convex lens is equal to twice the length of its radius, or what is equivalent to the same thing one-half its refractive power. Applying this rule we find the combined power of the two surfaces is 4 D., one-half of which is 2 D., and this represents the power of the lens.

In what three ways may light be affected?

It may be refracted, reflected or absorbed. Or its velocity may be increased or diminished, or bent out of its course.

What is an image and how is it formed?

An image is the exact reproduction of an object, and is formed by refraction through a lens or reflection from a mirror.

There are two kinds of images, real and virtual. The first is formed by a meeting of the rays, it has an actual existence and may be projected upon a screen. The second is only an imaginary image such as would be formed by a prolongation backward of the diverging rays of light.

What is a ray of light called before passing from one medium to another?

An incident ray.

What is a ray of light called after it has passed from one medium into another?

A refracted ray.

What is spherical aberration?

Spherical aberration is the wandering of rays from a single

focus, or the focusing of the rays of light passing through a lens at varying distances from the lens, the rays passing through the periphery coming to a sooner focus than the more central rays. This is due to the fact that the curvature and therefore the refractive power of the lens increases from the center (where it is nothing) to the periphery (where it is greatest).

What is chromatic aberration?

Chromatic aberration is due to dispersion of light on account of the difference in refraction of the different colors of which white light is composed. As a result in the image formed by an ordinary lens, the outlines of the figures will be found to be edged with rainbow hues. The seven primary colors each have a different degree of refrangibility, the red being least refracted, the violet most, the other colors in regular order between these extremes.

If light is reflected away from the normal or perpendicular, what is the cause? If toward the perpendicular?

In the first case on account of the passage of rays from a dense to a rare medium; and in the second case the passage of light from a rare to a dense medium.

What is a virtual focus?

This is synonymous with a negative focus, and is the point from which rays appear to diverge after passing through a concave lens, or after reflection from a convex mirror, or after refraction by convex lens when object is closer than its principal focal distance, or after reflection from a concave mirror when object is closer than its principal focal distance.

What is reflection of light?

This is the throwing back of rays of light from the surface on which they fall into the same medium through which they came. The best form of a reflector is a mirror or a polished metal surface. But even if the body is transparent and the rays are

transmitted, yet some of them are reflected and it is by these reflected rays that objects are made visible.

What is refraction of light?

The deviation which takes place in the direction of a ray of light as it passes from one medium into another of different density. The two laws that govern refraction are:

1. In passing from rare to dense medium, bent *toward* the perpendicular.
2. In passing from dense to rare medium, bent *from* the perpendicular.

Where is the principal focus of a lens?

At the principal focal distance of a lens, that is where parallel rays are made to meet after being refracted by a convex lens. If the rays that enter the lens are convergent or divergent instead of parallel, the focus would be shortened or lengthened, but it would not be the principal focus.

What are conjugate foci?

The point from which rays originate and diverge and the point on the other side of the lens on the axial ray where they come together are conjugate to each other, and are known as conjugate foci. Either one may be considered as the object and the other will be the image.

What is the difference in the image as formed by a concave spherical mirror and a convex spherical mirror?

Assuming the object to be at a distance so that the rays that strike the mirror are parallel, the image formed by a concave mirror is real, inverted, and in front of the mirror and can be caught upon a screen; while that formed by a convex mirror will be virtual, erect, behind the mirror and cannot be caught upon a screen.

What is the conjugate focus to a point which is 2 inches from a minus lens with a principal focus of 3 inches?

If the source of light is at a distance of 2 inches the rays of light would have a divergence equal to − 20 D., which will be increased to 33 D. by passing through a concave lens with a divergence of 13 D., as shown by the principal focus of 3 inches. This 33 D. will show a virtual focus at about 1 1/5 inches on the same side of the lens as the object is situated; and therefore 1 1/5 inches would be conjugate to 2 inches in this case.

A plus lens has a principal focus of 40 cm. and the radius of curvature of one of its surfaces is 40 cm.; what is the radius of curvature of the other surface, the index of refraction of the glass being 1.5?

In a biconvex lens the focal length is just equal to its radius; therefore in this case, where the principal focus is identical with the radius of curvature of one of its surfaces, the lens must be biconvex and the radius of the second surface the same as that of the first, viz., 40 cm.

If the index of refraction of a certain kind of glass is 1.496 on what radius of curvature must a plano-convex lens be struck so that the lens will be a 1 D. lens?

The rule is, focal distance, multiplied by index of refraction equals radius of curvature if the lens is plano. Substituting figures, we have

$$40\ (1\ \text{D.}) \times (1.496 - 1)$$
$$\text{or } 40 \times .496 = 19.84$$

The radius of curvature would have to be 19.84 inches.

What is the critical angle in refraction and what is the result of same?

This is the least angle of incidence that permits a ray of light traveling in a dense medium to pass into a rare medium, and beyond which total reflection occurs at the surface which separates the two media. As this prevents any loss of light from transmission or absorption, the reflection will be the most brilliant

obtainable, and hence this method is made use of in optical instruments.

The critical angle from water to air is 48° 35′, which means that this is the least angle that will permit the light to be refracted and pass out of the water. If the rays form an angle greater than 48° 35′, they will not pass out of the water but will be reflected back into it. The surface separating the two media becomes a reflecting surface and acts as a plane mirror.

What is the conjugate focus to a point 36 centimeters from a biconvex lens of 2.5 D.?

A convex lens of 2.50 has a principal focal distance of 40 cm., and rays proceeding from this point would emerge from the lens parallel. If they proceed from a point farther than the principal focus they will emerge from the lens convergent and will meet at a point which is conjugate to that from which it proceeded. On the other hand, if the rays proceed from a point closer than the principal focus, they will emerge from the lens as divergent and will not meet in a focus.

The latter is the condition that applies in this question, the principal focus being at 40 cm. and the rays proceeding from a point at 36 cm. The rays will emerge still divergent, but not so much so as before entering the lens. If these divergent rays were continued backward by imaginary lines to the point from which they *appear* to proceed, that point would be conjugate to the first, although it is a negative focus and has no real existence.

The question is, where will that point be located in the case under consideration? Rays proceeding from 36 cm. will have a divergence equal to 2.85 D. After passing through the + 2.5 D. lens and being refracted to that extent, they will emerge with a divergence equal to .35 D., which represents a distance of 114 inches, or 285 cm. which in this case is conjugate to the 36 cm.

What general effect do plus and minus lenses have on diverging and converging light?

Convex lenses act on diverging rays so as to lessen their divergence. If the rays proceed from some distance or from a point beyond the principal focus, the divergence will be entirely

overcome and the rays made convergent and brought to a focus. If proceeding from its principal focus, the convex lens would make them parallel. If proceeding from a point closer than the principal focus, the convex lens would reduce their divergence.

The convex lenses act on converging rays in such a way as to make them more convergent and bring them to a sooner focus.

Concave lenses act on divergent rays in such a way as to increase their divergence.

Concave lenses act on convergent rays to lessen their convergence. If their divergence corresponded with the lens they would emerge parallel; otherwise they would meet in front of or beyond the negative focus of the lens, depending upon the degree of their divergence.

A certain lens focuses parallel light at 20 cm.; what lens must be placed in front of it to send the focus back to one meter?

The lens in question must be convex and if it focuses parallel rays at 20 cm. this must be its principal focal distance, in which case the lens would be + 5 D.

In order to throw the principal focus back to one meter, the strength of the lens must be reduced to + 1 D. which can be accomplished by placing in front of the original lens a − 4 D.

What is the strength of a lens that causes light coming from a point 133 cm. away to pass out parallel?

If light emerges from a lens in parallel lines it must come from a point at the principal focus of the lens, because the latter is conjugate with infinity, as represented by the parallel lines. Therefore the strength of the lens is approximately .75 D., which is found by dividing 133 cm. into 1 meter (or 100 cm.).

What is the index of refraction when light passes from water into glass, the latter having a refractive index of 1.546?

The law of refraction is expressed by the following formula:

$$\frac{\text{Sine angle incidence}}{\text{Sine angle refraction}} = \text{index of refraction.}$$

This constant quantity, which is known as index of refraction, represents the relative velocity of light in the two media, the

greater the density the less the velocity. The sine of the angle of incidence always bears the same numerical relation to the sine of the angle of refraction, no matter what the angle of incidence may be.

The index for two media with reference to each other is obtained by dividing the refractive index of one into the refractive index of the other.

In this question we have the refractive index of glass given as 1.546, which we divide by the refractive index of water (1.333),

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1.333)1.546(1.1597
      1.333
      -----
       2.130
       1.333
       -----
        7.970
        6.665
        ------
        1.3050
        1.1997
        ------
        1.0530
         .9331
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A certain lens in air has a power of 6 diopters, the refractive index of the glass being 1.562; what will be the dioptric power of this lens when submerged in water?

In order to obtain the refractive index for water and glass with reference to each other, we divide the index of glass (1.562) by the index of water (1.333), and the result is 1.171.

In order therefore to compare the power of the lens in water with its power in air, we must make use of the proportion of the refractive index of one to the other.

$$x : 6\text{ D} :: .171 : .562$$

$$x = 6\text{D} \times \frac{.171}{.562} = 1.82\text{ D.}$$

Therefore the power of this 6 D. lens when submerged in water is reduced to 1.82 D.

A plus 8 D. lens made of glass of refractive index of 1.523 is cemented inside of two plates ground with curves to match its surfaces, but of index of refraction of 1.634; what is the power of the lens in its new position?

In order to obtain the refractive index of these two kinds of glass with reference to each other, we divide the index of one (1.523) into the index of the other (1.634) and the result is 1.073, which is the refractive index of the lens as it is enclosed in the two plates of glass.

In order to ascertain its power we have the following proportion:

$$X : 8\text{ D} :: .073 : .523$$

$$X = \frac{8 \times .073}{.523} = 1.11\text{ D.}$$

Therefore the power of this 8 D. lens inside the enclosing plates of glass has been reduced to 1.11 D.

An 8 D. lens is decentered 4.5 mm.; what is the prismatic effect of the deviation in prism diopters?

The unit of measurement is 1 p. d. for each diopter of refractive power, when decentered 10 mm.

An 8 D. lens decentered 10 mm. = 8 p. d.
" " " " 1 mm. = .8 p. d.
" " " " 4.50 mm. = 3.6 p. d.

The prismatic effect of an 8 D. lens decentered 4.5 mm. is 3.6 p. d.

An object is placed 9 inches in front of a lens and an image of this object is formed at 18 inches from the lens on the other side; what is the principal focus of the lens in inches? Make the calculation.

$$\frac{1}{0} + \frac{1}{i} = \frac{1}{f}$$

or substituting figures

$$\frac{1}{9} + \frac{1}{18} = \frac{3}{18} \text{ or } \frac{1}{6}$$

The principal focus of this lens is 6 inches.

How are rays of light reflected from plano, concave and convex mirrors?

No matter whether the surface is plano, concave or convex, the laws of reflection are always the same, viz.:

The angles of reflection and incidence are equal.

The incident and reflected rays are always in a plane perpendicular to the reflecting surface.

In the case of a plane mirror the incident ray is reflected in the opposite direction at the same angle.

In the case of a concave mirror the rays are reflected according to the same law, and if parallel are converged to a point which is the principal focus of the mirror, and is approximately half its radius of curvature.

In the case of a convex mirror the rays of light according to the same law are reflected divergently.

The index of a certain substance is stated to be 1.564; what is the meaning of this statement?

By the index of refraction of a substance is meant its relative density or the comparative length of time required for light to travel a definite distance in different substances. The greater the density the slower the velocity, and the smaller the angle of refraction.

The index of refraction is found by dividing the sine of the angle of incidence by the sine of the angle of refraction. In this particular case the result was 1.564 which has been determined with reference to air, the index of which is regarded as unity. Or, in other words, the lessened rapidity with which light passes through this substance as compared with air, the ratio being 1 to 1.564.

When a ray of light passes from a denser to a lighter medium. which way is the ray bent?

According to the laws of refraction in passing from a dense to a rare medium, as from glass into air, if the ray is oblique it is bent from the perpendicular. If the ray impinges upon the second medium at right angles it passes unrefracted.

An object is 24 inches high and it is 60 inches from a lens; the image of this object is 10 inches from the lens; what is the height of the image?

If i is size of image, o size of object, $d\ i$ distance of image, and $d\ o$ distance of object, the proportion is expressed as follows:

$$i : o :: d\,i : d\,o$$

Substituting the figures in the above question we have

$$X : 24 :: 10 : 60$$

$$X = \frac{240}{60} = 4 \text{ inches.}$$

An image formed by a certain lens is 5 mm. wide and at a distance of 200 mm. from the lens. The object is 4 meters distant; how wide is it?

Using the same proportion and substituting figures we have

5 mm. : x :: 200 mm. : 4 m. or 4000 mm.

$$X = \frac{20000}{200} = 100 \text{ mm}$$

This is equivalent to 10 cm. or 1/10 meter.

The distance of an object from a certain lens is 24 feet (288) inches; the distance of the image of this object from the lens is 6 inches on the same side of the lens as the object; what is the principal focus of the lens?

If we assumed that the rays from 20 feet and beyond were parallel then these rays from 24 feet forming an image at 6 inches would indicate this distance as the principal focus, and as the image is on the same side of the lens as the object, it must be virtual and the lens concave.

To work it out accurately we use this general formula:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

in which o represents the distance of the object, i the distance of the image, and f the principal focus of the lens.

Substituting figures we have

$$\frac{1}{288} + \frac{1}{6} = \frac{49}{288} \text{ or } 5.88 \text{ inches.}$$

In this case the focus is .12 or 1/8 inch closer than if we assumed the rays to be parallel.

The principal focus of a certain plus lens is 10 inches; the object is placed 20 inches from the lens; where will the image of the object be found?

$$\frac{1}{o} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$$

Image of object will be found at 20 inches.

An object is ½ meter from a + 6 D. lens; where will the image be?

Using the regular formula and substituting values,

$$\frac{1}{o} = 6\text{ D.} - 2\text{ D.} = 4\text{ D.}$$

$$\frac{1}{o} = \frac{1}{4}\text{ meter.}$$

The image will be ¼ meter from the lens.

A certain plano-convex lens has a principal focus of 40 mm. and the index of refraction of the glass is 1.620; what is the radius of curvature of the convex surface?

The rule is that the focus multiplied by index of refraction less unity equals radius of curvature.

Substituting values

$$40\ (1.620 - 1) = 40 \times .620 = 24.8.$$

The radius of curvature of the convex surface is 24.8 mm.

A certain lens has an index of 1.500, one surface being on a radius of 12 inches and the other on a radius of 24 inches; what will be the principal focus of the lens?

Inasmuch as the refractive index is exactly 1.50, and no more, we may say that the focal length of a plano-convex lens is equal to twice the length of its radius. Therefore, the focal length of the 12-inch surface is 24 inches, and of the 24-inch surface, 48 inches.

Then applying our formula we have

$$\frac{1}{24} + \frac{1}{48} = \frac{3}{48}, \text{ or } \frac{1}{16}$$

That is, the principal focus is 16 inches from the lens.

In transposition of lens power does the cylinder ever change in value? What is the reason?

In transposition of sphero-cylindrical lenses the number of the cylinder must always remain the same, although there is a change in its sign and in the position of its axis. The amount of the cylinder cannot be changed because it represents the degree of astigmatism or the difference in power between the meridians of least and greatest curvature. This is an important point for the student to remember, because if he loses sight of it he soon falls into error in working out problems in transposition.

How is it possible to measure the strength of a plus lens without using either neutralizing lenses or a lens measure?

By measuring its focal distance. By allowing the rays from an object at least 20 feet distant, as a tree, or a house, or a sign, to pass through the lens and form an image on a screen. The lens is slowly moved closer to and farther from the screen until the image is found to be the most distinct, and then the distance of the lens from the screen will represent the principal focal distance of the lens, which can then be converted into diopters to show its refractive power.

Object is 14 inches high and its distance from a 2-inch focus concave mirror is 40 inches; what is the height of the image?

First we must find the distance of the image. If distance of object is 40 inches from a 2-inch concave mirror the distance of image is found by the following formula:

$$\frac{1}{2} - \frac{1}{40} = \frac{19}{40}$$

That is, image is at 2 2/19 inches.

Now then, in order to find the height of image, we make use of the usual proportion

$$40 : 14 :: \frac{40}{19} : X$$

X = 14/19 of an inch, which is the height of the image.

Object is 80 inches high, its image is 2 inches high, the mirror being convex. The distance of the object from the mirror is 80 inches; what is the principal focus of the mirror?

If an object is 80 inches high and its distance is 80 inches, then if the image is 2 inches high its distance will be 2 inches.

Having the distance of the object (80 inches) and the distance of the image (2 inches), the principal focus of the mirror is found by the following formula:

$$-\frac{1}{2}-\frac{1}{80}=-\frac{39}{80} \text{ or } -2\frac{2}{39} \text{ inches}$$

A 3-inch concave mirror forms an image of a certain object, the object 1½ feet high and the image 1½ inches high. How far away is the object from the mirror?

We have the size of object and the size of image, and in order to find distance of object, we must work out the distance of image as the third proportion.

The object is twelve times the size of the image, therefore the distance of object must be twelve times that of image. The whole focal distance is 3 inches, of which 12/13 represents distance of image and 1/13 distance of object.

$$\frac{1}{13} \text{ of } \frac{1}{3}=\frac{1}{39}$$

that is, 39 inches is the distance of object from the mirror.

This can be proven by finding the distance of image as 12/39, and then using formula:

$$\frac{1}{39}+\frac{12}{39}=\frac{13}{39} \text{ or } \frac{1}{3}$$

or 3-inch focus.

An object which is 2 feet wide is at a distance of 8 feet from a 4 D. convex mirror; what is the width of the image?

In a convex mirror the focus is negative, but otherwise the rules governing the calculations of conjugate foci are the same as with a concave mirror.

In this case we have the distance of the object and the principal focal distance of the mirror, and we get the distance of the image by the following formula:

$$-\frac{1}{10} - \frac{1}{96} = -\frac{1}{9\frac{3}{53}}$$

The image is virtual and $9\frac{3}{53}$ inches behind the mirror.

Now then we find the width of the image by the following proportion:

$$96 : 24 :: 9\ 3/53 : X$$

Or as the size of the object is ¼ of its distance, so the size of the image will be ¼ of its distance.

$$X = \tfrac{1}{4} \text{ of } 9\ 3/53 = 2\ 14/53 \text{ inches}$$

That is, the image will have a width of $2\frac{14}{53}$ inches.

An object which is 12 inches in diameter is 40 feet from a concave mirror. The image of the object formed by the mirror is 4 inches in diameter. On what radius is the mirror surface formed?

In the first place we find the distance of the image by the following proportion:

Size Object		Distance Object		Size Image		Distance Image
12 in.	:	480 in.	: :	4 in.	:	X

$$X = \frac{480 \times 4}{12} = 160 \text{ inches}$$

Having the distance of the object and the distance of the image, we find the principal focal distance by the following formula:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

Substituting figures

$$\frac{1}{480} + \frac{1}{160} = \frac{4}{480} \text{ or } \frac{1}{120}$$

120 inches, or 10 feet is the focus of the mirror.

And as the radius of curvature of a concave mirror is twice the principal focus, in this case the radius on which the mirror surface is formed must be 20 feet.

An object is 20 feet from a convex mirror. Its height is six times as great as the height of its image; what is the principal focus of the mirror?

If the height of the image is 1/6 the height of the object, then the distance of the image must be 1/6 the distance of the object; this would give us 40 inches as the distance of the image.

The distance of the object being 240 inches and of the image 40 inches, we find the principal focus of the mirror by the following formula, always remembering that in a convex mirror the focus is negative. $\frac{1}{40} - \frac{1}{240} = \frac{5}{240} = \frac{1}{48}$

48 inches is the principal focus of the convex mirror.

What is the radius of curvature of the second surface of a lens, of which the first surface has a radius of curvature of 10 cm., the principal focus of the entire lens being 25 cm., and the index of refraction being 1.5?

If the radius of curvature of the first surface of the lens is 10 cm., its focal length would be twice that of the radius, or 20 cm., which is equivalent to a dioptric power of + 5 D. The principal focus of the entire lens is 25 cm., which is equivalent to + 4 D. Hence the dioptric power of the second surface of the lens must be — 1 D., which would correspond to a focal length of 100 cm. and a radius of 50 cm.

An object 3 inches in diameter is placed in front of a concave mirror at such a point that its image is formed 4 inches from the mirror, the diameter of the images being ½ inch; what is the focus of the mirror?

In this example the distance of the image is 4 inches and its size ½ inch; that is, the distance is eight times the size, therefore the distance of the object would be eight times its diameter; the latter being 3 inches, the former would be 24 inches.

Then we find the focus of the mirror by the usual formula:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \qquad \text{or} \qquad \frac{1}{4} + \frac{1}{24} = \frac{7}{24} \text{ or } \frac{1}{3\frac{3}{7}}$$

3 3/7 inches is the focal distance of the mirror.

Transpose the following to two forms of sphero-cylinders: + 1 cyl. ax. 90° with 1 cyl. ax. 180°.

+ 1 D. sph. ⊃ − 2 D. cyl. ax. 180°, and
− 1 D. sph. ⊃ + 2 D. cyl. ax. 90°

When a ray of light passes through a denser medium than air—a piece of glass for instance—and it is apparently bent or refracted from a straight line, why does it not continue in the same course after emerging from the glass that it assumes while passing through the glass? Why does it change back to the same angle as before entering the glass?

Because it is subject to the laws of refraction, and hence in passing from a rare to a dense medium, as from air into the piece of glass, it is bent *toward* the perpendicular; and in passing from a dense to a rare medium, as when it emerges from the glass into air, it is bent *from* the perpendicular. The amount of bending in each case is equal, and hence the emergent ray is parallel to the entering ray.

A certain lens has one surface convex on a radius of four inches, and the other surface convex on a radius of ten inches; index of refraction 1.60; what is the power of the lens?

The focal distance of each surface is found by dividing the radius of curvature by the index of refraction, less one.

$$\frac{4}{(1.60-1)} = \frac{4}{.60} = 6\ 2/3 = 6\text{D.}$$

$$\frac{10}{(1.60-1)} = \frac{10}{.60} = 16\ 2/3 = 2.50\text{D}$$

6 D. + 2.50 D. = + 8.50 D. approximately the power of the lens.

Why is it that as a lens is moved from side to side a distant object seen through the lens seems to have a movement of its own?

Because at every point except at its optical center the lens will show a prismatic effect, and because the effect of a prism is to cause displacement in the direction of its apex. In a

lens the prismatic effect increases from the center to the periphery, and hence as a lens is moved from side to side and the visual line passes through the lens at different points from center to periphery the prismatic power of the lens comes into evidence and causes displacement. As the lens is kept moving the displacement shows itself as a movement of the object, which in concave lenses is in the same direction, and in convex lenses opposite.

In what direction relative to each other do rays of light travel when first leaving a luminous point?

Divergently.

What effect do the following have upon parallel light: Convex sphere, concave sphere, plano-convex cylinder?

Convex sphere converges to a focal point; concave sphere diverges as from a focal point, and convex cylinder converges to a focal line.

What three things happen to a ray of light incident on a glass surface? Refraction (if the surface is curved), reflection and absorption.

State a rule for the transposition of a compound to its equivalent form which will apply to both minus and plus forms of compounds.

The new sphere is obtained by the algebraic addition of the sphere and cylinder, and the new cylinder retains the number of the old one but changes its sign and axis.

What is the dioptric power of a plus lens with a focus of 984 inches, the index of refraction being 1.742?

In a case where the radius of curvature is given we must know the index of refraction in order to figure out the focal distance of the lens. But in a question like this, where the focal distance is given with a desire to transpose it into diopters, the index of refraction is not taken into account, but we simply

divide the inch number into 40 and the result will be .04 D., or approximately 1/25 of a diopter.

What is the radius of curvature for the two surfaces of a + 3 D. lens with a − 9 D. surface on the inner side, index 1.57?

If the concave surface of this + 3 D. lens is − 9 D. the convex surface is + 12 D.

In this case where the index is 1.57 we solve the problem as follows:

$$3.33 \times (1.57 - 1) = 1.89 \text{ inches}$$
$$4.50 \times (1.57 - 1) = 2.56 \text{ inches}$$

To find the radius of curvature for the surface of a lens we are told to deduct unity from the index of refraction; what does this mean, and give an example that will apply in practice?

If the index of refraction is 1.54 and we deduct unity, there would be left .54, which is the excess above unity and the amount in which we are interested.

Suppose the focal length of the lens was ten inches, the problem would be focal length multiplied by index of refraction less unity equals radius of curvature, or $10 \times (1.54 - 1) = 10 \times .54 = 5.4$. In this case if the focal length is ten inches and the index of refraction 1.54 the radius of curvature is 5.4 inches.

What is the fundamental reason for light being refracted as it passes from one substance into another?

Because of the difference in the density or index of refraction of the two substances. If light would pass from one substance into another, both of the same density, there would be no refraction. As the density of a substance increases, the velocity of light is diminished and then refraction takes place.

Find the radius of curvature of a lens for its two surfaces, each surface to be alike and each to measure one diopter. Index of glass, 1.632.

Multiply the focal length by twice the index of refraction less one. In this case where the two surfaces each measure one diopter the focal length of the lens is twenty inches.

The problem is

$$20 \times 2\,(1.632 - 1)$$

or,

$$20 \times 1.264 = 25.28 \text{ inches,}$$

which is the radius of curvature.

How would you transpose the following cross-cylinder into an equivalent sphero-cylinder without using a mathematical formula for the same: + .75 cyl. axis 120° combined with − 2 cyl. axis 60°?

I would take these two cylinders from the trial case and place them in the positions indicated in the trial frame. Then I would look through this combination at a straight line and locate the two principal meridians, which I would then proceed to neutralize with convex or concave spheres. Or, in other words, inasmuch as this obliquely crossed cylinder is equivalent to a sphero-cylinder, I would neutralize the combination in the same way that any sphero-cylinder would be neutralized. Then the opposite of this neutralizing combination would be the transposition desired.

With a candle flame one meter from two + 3 D. lenses placed 13 inches apart, where should the screen be placed to receive a perfect image of the candle flame?

The divergent rays from the candle 40 inches away after being refracted by the first lens are converged to a point 20 inches on the other side of the lens, but on their way they meet the second lens placed 13 inches from the first, and they are then convergent to a point 7 back of the second lens (20 − 13 = 7). The effectivity then of the first lens in the plane of the second lens is that of 1/7, or the effect is the same as if a 7-inch lens was placed in contact with the second lens, and the screen to receive a perfect image of the flame would be placed at 4 11/20 inches being found as follows:

$$\frac{1}{7} + \frac{1}{13}\ \frac{20}{91} \text{ or } 4\ \frac{11}{20} \text{ inches}$$

If F_r = resultant focus,
If F_1 = focus of first lens,
If F_2 = focus of second lens.
If d = distance between the two lenses, then the effective focal distance is found by the following formula:

$$Fr = \frac{(F_1 - d)\ F_2}{F_1 + F_2 - d}$$

Substituting figures we have

$$Fr = \frac{(20 - 13) \quad 13}{20 + 13 \quad - 13} = \frac{7 \times 13 = 91}{33 - 13 = 20} = 4\frac{11}{20} \text{ inches}$$

What is the rule to figure the curvatures of the surfaces of lenses?

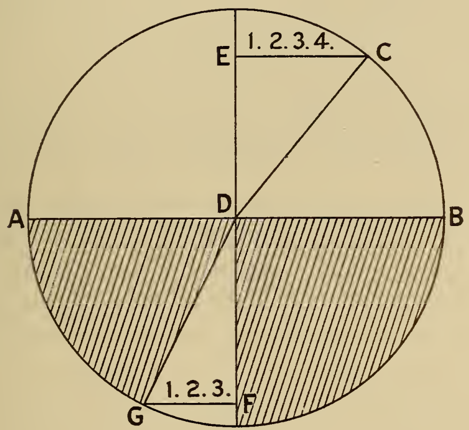


FIG. 9. (See next page)

Focus multiplied by index of refraction less unity = radius of curvature.

For instance, take a 20-inch lens of an index of refraction of 1.62.

$$20\ (1.62 - 1) = 12\ 4/10 \text{ inches.}$$

Or if we wished to use the metric system we would say that with an index of refraction of 1.62 the radius of curvature for a 1 D. surface is 62 cm. and for a 2 D. surface 31 cm., which corresponds to the answer of 12 4/10 inches found above.

What happens when light strikes a polished opaque surface and a polished transparent surface?

When light falls upon a polished opaque surface it is practically all reflected. When it falls upon a polished transparent surface it is nearly all transmitted, although there is some reflection.

What is meant by index of refraction? Give example to find relative index of water.

Commonly we understand it to be the refractive or bending power of a medium as compared with air, which is standard, and the index of which is unity. The index of refraction depends upon the relative density of a substance or the comparative length of time required for light to travel a definite distance in different substances. The greater the density the slower the velocity and the more the refractive power.

In order to find the index of refraction of any substance as compared with air we divide the sine of the angle of incidence by the sine of the angle of refraction. (See Fig. 9 on preceding page.)

Let $A\ B$ be the refracting surface separating air from water. Let $C\ D$ be a ray incident on the surface at the point D, to which the line $E\ D\ F$ is the perpendicular. The $C\ D\ E$ is the angle of incidence and $G\ D\ F$ is the angle of refraction. Then $E\ C$ is the sine of the angle of incidence and $G\ F$ the sine of the angle of refraction.

We divide the sine of the angle of incidence (4) by the sine of the angle of refraction (3), and the answer is 4/3, or 1 1/3, or 1.33, which is the index of refraction of water as compared with air.

When does a real image produced by a plus lens change to a negative image?

When the object is closer to the lens than its principal focal distance the rays will emerge divergently and the image will be a negative one.

What is the rule for the transposition of a sphero-cylinder into its equivalent form?

The *new sphere* is obtained by the algebraic addition of the sphere and cylinder of the old combination.

The *new cylinder* retains the same number or dioptric value as the old one, but there is a change of sign and axis.

If a + 4 D. lens is so placed in relation to light that it forms an image of the light 100 feet away, what is the relative size of object and image?

If the image is formed at a distance of 1,200 inches from a ten-inch lens, then the distance of the object is found by the following equation:

$$\frac{1}{10} - \frac{1}{1200} = \frac{119}{1200}$$

If the distances of image and object are as 1 to 119, the relative sizes will be in the same proportion.

What is the radius of curvature of a double convex lens of 5 D. of power, the refractive index of the glass being 1.542?

When glass has a refractive index of 1.50 the radius of curvature of a biconvex lens and its focal distance are equal.

But in this case where the index is 1.542 the radius of curvature of this eight-inch focus lens is $8\,{}^{672}\!/_{1000}$ inches, as found by the following formula:

$$8 \times 2\,(1.542 - 1) = 8 \times 1.084 = 8.672$$

What is the refractive index of a plano lens of 2 D., the radius of curvature being 25 cm.? How do you make the calculation?

We divide the focus into the radius, as 25 cm. divided by 50 cm. (the focal length of a 2 D. lens) equals .50. This being the amount above unity, the index of refraction is 1.50.

What is the focal length of two lenses placed in contact whose powers are + 3 D. and + 5 D.?

The two lenses would be equivalent to a + 8 D. lens with a focal length of five inches.

Transpose the following so as to eliminate spheres:

(a) + 5 D. sphere = − 4 D. cyl. axis 10°
(b) + 4 D. sphere = − 4 D. cyl. axis 120°

(a) In this case we can eliminate the sphere only by transposing into a cross-cylinder, as follows:

+ 1 D. cyl. axis 10° = + 5 D. cyl. axis 100°

(b) In this case, where the sphere and cylinder have the same value, the sphere can be eliminated by transposition into a plano cylinder, as follows:

+ 4 D. cyl. axis 30°

Transpose the following sphere cylinder to its equivalent form and explain how you do it:

+ 1 D. sphere = − .50 D. cyl. axis 120°

The new sphere is obtained by the algebraic addition of the sphere and cylinder, as − .50 added to + 1 = + .50 D., which is the new sphere.

The new cylinder has the same value as the old one, but its sign and axis changes from − .50 D. to + .50 D. and from axis 120° to axis 30°.

The completed transposition is: + .50 D. = + .50 D. cyl. axis 30°.

Define (a) a ray of light; (b) a pencil of light.

(a) The smallest subdivision of light traveling in a straight line and perpendicular to a wave front.

(b) A bundle of light, cone-shaped and composed of convergent or divergent rays.

When light falls upon a transparent plate, what is the incident ray and which is the emergent ray?

The incident ray is that which strikes the plate after leaving the luminous point. The emergent ray is that which leaves the plate after having passed through it.

What three things may happen to light when it falls on a surface?

Reflected, absorbed and transmitted or refracted.

Are rays of light coming from an object plus or minus?

Rays of light coming from an object are divergent and might be considered as minus, because they require a convex lens to overcome the divergence and make them parallel.

What are the conjugate foci of a lens?

The location of object and image which are interchangeable.

What is a real focus and what is a virtual focus? Give an example of each.

A real focus is formed by the actual meeting of rays after refraction by a convex lens and can be caught on a screen.

A virtual focus is formed by the imaginary continuation backward of divergent rays, as in the case of a convex mirror.

At what distance from the surface of the mirror will parallel light be focused, if the radius of curvature of the mirror is 20 inches?

The principal focal distance of a concave mirror is approximately one-half the radius. Therefore, in this case, where the radius is 20 inches, parallel rays would be focused at 10 inches.

Transpose the following:

(a) $-3.25 \supset +1.50$ *cyl. axis 45°*
(b) $+ .75 \supset - .75$ *cyl. axis 90°*

(a) -1.75 sph. $= -1.50$ cyl. axis 135°
(b) $+.75$ cyl. axis 180°

What is the combined value of $+3, -1, +4, -6$*?*

Zero.

From -2.50 *take away* $+3.25$

-5.75.

Change + .12 ⊃ − .25 cyl. axis 50° to its equivalent sphero-cylinder.

− .12 ⊃ + .25 cyl. axis 140°.

Change the following to its equivalent periscopic form:

+ 1.25 sph. ⊃ + 1.25 cyl. axis 120°

+ 2.50 D. sph. ⊃ − 1.25 D. cyl. axis 30°

Transpose to corresponding sphero-cylinders:

(a) − .50 ⊃ + .75 cyl. axis 15°
(b) + .50 cyl. axis 50°
(c) + .50 ⊃ − .75 cyl. axis 45°
(d) − .50 cyl. axis 90°

(a) + .25 D. sph. = − .75 D. cyl. axis 105°
(b) + .50 sph. ⊃ − .50 cyl. axis 140°
(c) − .25 sph. ⊃ + .75 cyl. axis 135°
(d) − .50 sph. ⊃ + .50 cyl. axis 180°

Does the speed of light bear any relation to the index of refraction, and if so, what?

The velocity of light is lessened in media denser than air, the decrease in speed being roughly proportionate to the density. The velocity of light in the first medium is to the velocity of light in the second medium as the index of refraction of the second medium is to the index of refraction of the first medium. Or, in other words, the rate of progression of light in a medium is inversely proportional to its optical density. For example, if the index of refraction of glass was 1.50 or 3/2, then the speed of light as it passes from air into this glass is reduced to 2/3.

When light falls vertically upon a plane glass surface, what change is produced, if any?

The light would pass unrefracted, the only change being that its speed would be reduced to two-thirds approximately.

How can the existence of refraction be shown with a penny and a cup of water?

The penny is placed at the bottom of the cup, with the eye of the observer in such a position that it cannot be seen. The cup is filled with water, and without any change in the position of the eye, the penny comes into view.

In what way does a light wave differ from a ray of light?

In studying the transmission of light, there is assumed to be a disturbance in the ether which exists throughout the universe, manifesting itself by a series of waves, which is usually likened to the familiar example afforded by throwing a stone into a pool of still water. Therefore the wave has a circular or spherical front.

A ray of light is the smallest conceivable line of light, and may be regarded as a straight line perpendicular to the wave front.

If we place a transparent solid in a transparent liquid, what is essential that the solid may be entirely invisible?

Both must have the same color and same density, or in other words, the same index of refraction.

When are two points conjugate foci and when not?

Two points, one on each side of a lens, are conjugate to each other when the rays diverging from one are converged to the other; or when one occupies the position of the object, and the other that of the image, and when these are interchangeable.

The center of curvature of a concave reflecting surface is one meter distant; what is the power of the mirror?

Parallel rays striking a concave surface are reflected from it convergently, and are made to meet at the principal focus of the mirror, which is just one-half the radius.

In this case the center of curvature or radius is one meter, then the principal focal distance is half-meter or twenty inches, which would indicate the power of the mirror to be 2 D.

When will a concave mirror not form a real focus?

When object is placed at the principal focal distance of the mirror, no image is formed because the rays are reflected parallel.

And when the object is placed closer than the principal focal distance, the focus is a negative one.

Why is the power of the crystalline lens so much less when it is in position in the eye than it is when it is measured outside of the eye?

Inasmuch as the refractive power of a convex lens is increased as it is moved a little farther from the eye, the power of the crystalline lens would be very much greater if placed in the position of spectacles about half-inch in front of eye than when it is *in situ*.

Then, again, when the crystalline lens is in position in the eye, it is in contact with the aqueous in front, with an index of refraction of 1.33, and the vitreous behind with the same index: whereas, when it is outside of the eye it is surrounded by air, with an index of 1.00. Therefore there is less refraction in the first case when the light passes from a medium with an index of 1.33 into one with an index of 1.43 (which is the crystalline lens), than in the second case above it passes from a medium with an index of 1.00 into one with an index of 1.43.

What is the difference between a ray of light, a beam of light, and a wave of light?

A wave of light represents the disturbance in the ether when light is in motion; a ray of light is the smallest conceivable line of light and indicates the direction in which the light travels; a beam of light is a collection of parallel rays, as for instance a sunbeam.

What effect do lenses have upon light coming from an object?

Lenses bend or refract the light and bring the rays to a focus and thus produce an image of the object. This applies only when the object is at a greater distance than the principal

focus of the lens. If the object was at the principal focal distance, the rays would emerge parallel; if closer than this, they would emerge divergently, and in neither of these two cases would an image be formed.

What is the cause of spherical aberration in lenses?

Spherical aberration is caused by the difference in refraction power of different parts of the lens, as a result of which the rays of light passing through the lens do not all come to a focus at the same point, but those passing through the periphery come to the sooner focus.

What is the cause of spherical aberration in mirrors?

On account of the spherical curvature of a mirror, the rays of light reflected from the peripheral portions do not come to a focus at the same point as those reflected from the central portions.

Does the speed of light increase or decrease when it passes from air to glass, and what is the change in the speed if the index of refraction of the glass is 1.50?

The greater the density of a medium the more light is retarded, therefore, as it passes from air into glass its speed is decreased, and this decrease is to 2/3 if the index of the glass is 1.50.

What becomes of the energy of light when it is absorbed?

When light is absorbed it ceases to exist as light, and it becomes manifest as heat.

How can the deviating power of a 1° prism at 20 feet be calculated?

A 1° prism will deviate light 1 cm. for each meter of distance. As twenty feet is equivalent to six meters, the deviation at this distance would be 6 cm.

What are the several meanings of the word refraction?

Refraction means bending and has reference to the deviation of rays of light as they pass from a medium of one density into a medium of a different density, as for instance in passing from air into a glass lens and then from that lens into air, the rays are refracted by the lens.

The refraction of the eye is its optical condition, or the manner in which it acts on the entering rays, whether bringing them to a focus on the retina, or in front of or behind it, these rays being refracted by the media of the eye.

What relation does index of refraction bear to speed of light?

As the index of refraction of a substance increases the speed of light decreases.

How far must a convex lens of 3 inches focal distance be placed from a candle in order that it may produce a real image of the candle frame three times as large as the flame itself?

Inasmuch as the distance of the object is to the distance of the image as the size of the object is to the size of the image; therefore, if the size of the image is to be three times the size of the object, its distance must be three times the distance of the object.

Let X = distance of object and 3 X = distance of image, then

$$4\,X = 1/3$$
$$X = 1/12$$
$$3\,X = 1/12 \text{ or } 1/4$$

Therefore the candle must be placed 4 inches from the lens in order that a real image may be formed, magnified three times.

A parallel beam of light passes through a convex lens of power + 2 D. and which is 3 inches in diameter. What is the size of the circular patch of light which it casts on a screen 10 inches distant?

These parallel rays of light will be brought by this lens to focal point at a distance of 20 inches. If these convergent rays are intercepted by a screen at a distance 10 inches, which is just one-half the distance between the lens and the focus, the patch of light will be exactly one-half the diameter of the lens, that is 1½ inches.

If an object is placed 12 inches in front of a plus lens whose focal length is 6 inches, where will the image be, and what are the two points called?

Let F represent focal length and O distance of object and 1 distance of image. Then the standard formula is

$$\frac{1}{0} + \frac{1}{1} = \frac{1}{F}$$

If any two of these quantities are known, the third can be found by this formula. In this case the distance of object and focal length are given, and in order to find distance of image the formula is

$$\frac{1}{F} - \frac{1}{0} = \frac{1}{1}$$

or substituting figures

$$\frac{1}{6} - \frac{1}{12} = \frac{1}{12}$$

The image will be at 12 inches and the two points are called conjugate.

If the eyes of fishes focus parallel rays of light when in the water, what would be the refractive conditions of such eyes when in air?

When the eyes of fishes are in water and light passes from the water into the cornea, there is no refraction because both have the same index of refraction, viz., 1.33. But when light passes from air with an index of 1.00 into the cornea with an index of 1.33, the rays are converged.

Now if under the first condition parallel rays are focused on the retina; under the second condition they would be focused in front of the retina; or in other words the refractive condition in air would be myopic.

A thin convex lens having a focal length of 3.5 inches, is placed in contact with two concave lenses having respectively focal lengths of 7.8 inches and 12.4 inches; what is the focal length of the combination?

We think the simplest way would be to transpose these focal lengths to dioptric powers and then make the necessary calculations.

7.8	focal length	=	5.05	dioptric power	
12.4	" "	=	3.17	" "	
3.5	" "	=	11.25	" "	

Then we have + 11.25 D. placed against − 8.22 D., and the resultant dioptric power will be + 3.03 D., which has a focal length of 13 inches.

These transpositions are made by dividing into 39.37, which are the number of inches in a meter.

What is the value expressed in a single lens of the following?

+ 2.50 sph.	=	*+ 2.50 cyl.*	*axis*	*90°*
− 1.25 "	=	*− 1.25 "*	*"*	*90°*
+ 4.00 "	=	*− 1.00 "*	*"*	*180°*
− 2.25 "	=	*− 2.00 "*	*"*	*180°*
− 3.00 "	=	*+ 1.00 "*	*"*	*90°*
+ 1.25 "	=	*− 0.75 "*	*"*	*90°*

In order to get the proper result all the cylinders must have the same axis; we can transpose either to 180° or 90°.

We will choose the latter as this requires only two transposition. Then we have

+ 2.50 sph.	=	+ 2.50 cyl.	axis	90°
− 1.25 "	=	− 1.25 "	"	90°
+ 3.00 "	=	+ 1.00 "	"	90°
− 4.25 "	=	+ 2.00 "	"	90°
− 3.00 "	=	+ 1.00 "	"	90°
+ 1.25 "	=	− 0.75 "	"	90°
− 1.75 sph.	=	+ 4.50 cyl.	axis	90°

This result being obtained by algebraic addition.

If an object at 20 inches from a convex lens has an image 20 inches on the other side, what is the power of the lens?

Rays reaching the convex lens from a distance of 20 inches would call for a convex lens of 2 D. to overcome their divergence, and in order that an image be formed at 20 inches on the other side of the lens, the rays leaving the lens must have such convergence as is produced by a convex lens of 2 D. Therefore, in order to accomplish both of these results the lens must have a power of 4 D.

Or if O is distance of object, and 1 is distance of image, and F is principal focal distance, the formula is

$$\frac{1}{0} + \frac{1}{1} = \frac{1}{F}$$

or substituting numbers

$$\frac{1}{20} + \frac{1}{20} = \frac{2}{20} \text{ or } \frac{1}{10}$$

Therefore 10 inches is the focal distance of the lens.

Why ought a person totally immersed in water to wear convex lenses in order to see distinctly?

In order that refraction may take place, the rays must pass from a medium of one density into a medium of a different density; as long as they continue in the same density there is no refraction.

Under natural conditions light passes from air with an index of 1.00 into the cornea with an index of 1.33, and is strongly refracted. But when immersed in water, light passes from the water with an index of 1.33 into the cornea with the same index, and without refraction.

Now, inasmuch as the refracting power of the cornea is neutralized by the water in contact with it, distinct vision would be impossible unless this neutralization of power is compensated for by a strong convex lens in front of the eye.

How far must a − 9 D. sphere and a + 8 D. sphere be placed from one another in order to neutralize each other? Does it make any difference which lens is in front of the other?

In order to produce neutralization these two lenses must be separated by the distance between their focal lengths.

Approximately the focal length of the + 8 D. lens is 5 inches and of the − 9 D. lens, 4½ inches, and the difference between the two is one-half inch, and roughly speaking the distance between the lenses should be one-half inch.

A more accurate way is to reduce to centimeters and subtract.

$$8 \text{ D.} = \frac{100}{8} = 12.5 \text{ cm.}$$

$$9 \text{ D.} = \frac{100}{9} = 11.1 \text{ cm.}$$

The difference between their focal lengths is 1.4 cm.

If the convex lens is in front the parallel rays would be refracted so as to meet at 12.5 cm., but at a distance of 1.4 cm. they meet the concave lens. At this point their convergent value is reduced to (12.5 − 1.4 cm.) 11.1 cm. and as the concave lens has an equivalent value in divergence, there is neutralization.

If the concave lens is in front parallel rays would be made to diverge as if from 11.1 cm., but at a distance of 1.4 cm. they meet the convex lens. At this point their divergence has increased to (11.1 cm. + 1.4 cm.) 12.5 cm., but as the convex lens has an equal amount of convergence, there will be neutralization.

A thin plano-convex lens made of dense flint glass, having an index of refraction of 1.7, has a radius of curvature of 15 inches for its curved surface; how can you find its focal length?

The formula is

$$\frac{1}{F} = \left(\frac{1}{r} + \frac{1}{r'}\right)(\mu - 1)$$

Or to express it in every-day language, the focal distance equals the radius of curvature of the first surface plus the radius of the second surface, and their sum multiplied by the index of refraction less one.

Substituting figures in the above formula:

$$\frac{1}{F} = \left(\frac{1}{15} + \frac{1}{0}\right)(1.7 - 1.)$$

$$\frac{1}{F} = \frac{1}{15} \times \frac{7}{10} = \frac{7}{150} \text{ or } 21.4 \text{ inches}$$

What is the formula that applies to the conjugate focal distances of a spherical mirror?

Conjugate foci are the positions occupied by the object and its image. They are interchangeable and when the object is at one, the image must be at the other. The rays diverging from one focus are converged to the other.

The letter F is used to represent the principal focal distance of a mirror, and its reciprocal (written $\frac{1}{F}$) would indicate its reflecting power. For instance, if 8 inches was the principal focal distance of a mirror, its power of reflection would be ⅛.

If f_1 be used to represent the distance of the object, then its reciprocal $(\frac{1}{f_1})$ would be the power that brings parallel rays to a focus at such distance.

If f_2 be used to represent the distance of the image from the mirror, then its reciprocal $(\frac{1}{f_2})$ would indicate the power which causes parallel rays to meet at such distance.

With a concave mirror the quantities are positive, and the full power of the mirror (represented by $\frac{1}{F}$) is equal to the sum of the powers which represent the distances of the object and image; or in other words, the reciprocal of the principal focal distance is equal to the sum of the reciprocals of any pair of conjugate foci, as follows:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

or

$$\frac{1}{F} - \frac{1}{f_1} = \frac{1}{f_2}$$

This is one of the most important formulae in optics. If any two of these quantities are known, the third can always be found.

The formula is universal and holds good for all spherical mirrors, both concave and convex, and also for lenses.

In what other way may the formula for conjugate focal distances be expressed?

If the letter A be used to represent the distance of the object

from the principal focus and the letter B the distance of the image, then

$$A\ B = F^2$$

or in other words, the distance of the object multiplied by the distance of the image equals the square of the principal focal distance.

Suppose we have an object placed 6 inches in front of a concave mirror of 10 inches focal distance.

The formula is

$$\frac{1}{F} - \frac{1}{f_1} = \frac{1}{f_2}$$

Substituting figures we have

$$\frac{1}{10} - \frac{1}{6} = -\frac{4}{60} \text{ or } -\frac{1}{15}$$

That is the image is 15 inches behind the mirror.

Using the second expression $A\ B = F_2$ we have by substituting figures:

$$4 \times 25 = 100$$

and 100 being the square of 10, which is the principal focal distance.

If an object be situated at sixty inches in front of a concave mirror of 20 inches focal length, where will the image be found?

Here we have the principal focal distance, which is F, and the distance of the object which is f_1. Then the reciprocal of the latter subtracted from the reciprocal of the former will equal the reciprocal of the distance of the image, as per the following formula:

$$\frac{1}{F} - \frac{1}{f_1} = \frac{1}{f_2}$$

Substituting figures

$$\frac{1}{20} - \frac{1}{60} = \frac{2}{60} \text{ or } \frac{1}{30}$$

The image if formed at a distance of 30 inches. In this case 30 inches and 60 inches are conjugate foci in respect to a 20-inch concave mirror, so that if the object is situated at a distance of 30 inches its image will be formed at a distance of 60 inches.

If an object be situated at sixty inches in front of a convex mirror of twenty inches focal length, where will the image be found?

Here we must keep in mind that the focal distance and power of a convex mirror are negative quantities, otherwise the rules governing the calculations of conjugate foci are the same as with a concave mirror. Therefore it must be expressed

$$-\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

or

$$-\frac{1}{20} - \frac{1}{60} = -\frac{1}{15}$$

The image would be a virtual one and situated 15 inches behind the mirror.

— 15 inches and 60 inches are conjugate to each other with respect to a 20-inch convex mirror, but not 15 inches and 60 inches; the 15 inches is a minus quantity. If the rays were convergent to a point 15 inches back of the mirror, on striking this 20-inch convex mirror their convergence would be so lessened that they would be reflected so as to meet at a point 60 inches in front of the mirror.

If an object one inch in diameter is placed 16 inches in front of a 24-inch mirror, what will be the size of the image?

In the first place we must find the distance of the image, for which we used the regular formula:

$$\frac{1}{24} - \frac{1}{16} = f_2 = -\frac{1}{48}$$

The image would be virtual and at a distance of 48 inches.

Let O represent the size of the object, and I the size of the image, and f_1 the distance of the object and f_2 the distance of the image.

Then the working formula is

$$\frac{O\ f_2}{f_1} = I$$

Substituting figures

$$\frac{1 \times 48}{16} = \frac{48}{16} = 3 \text{ inches.}$$

The size of the image is 3 inches.

Or we can get the result by the proportion given above,

$$X : 1 :: 48 : 16$$
$$X = 3$$

What is understood by Snellen's Law or the Law of Sines?

This has reference to the determination of the index of refraction of a substance as compared with air, and depends upon the relation of the angle of incidence to the angle of refraction, being expressed in the following formula:

$$\frac{\sin i}{\sin r} = \mu \text{ (a constant)}$$

This is known as Snell's Law, in honor of its discoverer, W. Snell, a Holland scientist, who died nearly three hundred years ago.

The direction of the refracted ray is not the same as that of the incident ray, but there is a definite relation between these two directions, as shown by the law above mentioned, which applies to any case where a ray of light meets the dividing line between media of different density, as between air and glass, air and water, etc.

When the light passes from a medium of less density into one of greater density, it is bent towards the perpendicular, when it follows that the angle of refraction is less than the angle of incidence, and under these conditions the index of refraction is greater than unity.

When light passes from a medium of greater density to one of less density, at the surface of separation of the two media, it is bent away from the perpendicular, and then the angle of refraction is greater than the angle of incidence, under which conditions the index of refraction is less than unity.

Inasmuch as nearly all transparent media are denser than air, their refractive indices are greater than unity, as shown by their deflection of light towards the perpendicular.

What is the focal distance of a lens with an index of refraction of 1.54 and its two surfaces having radii of 8 inches and 5 inches?

Let μ represent the index of refraction of the lens, r the radius

of curvature of the first surface, and r′ the radius of the second surface; then the power of the first surface is represented by the formula

$$\frac{\mu - 1}{r}$$

and the power of the second surface by

$$\frac{\mu - 1}{r'}$$

and the total power of the lens by

$$\frac{\mu - 1}{r} + \frac{\mu - 1}{r'} = \frac{1}{F}$$

or it may be written

$$F = \frac{r\ r'}{(r + r')\ (\mu - 1)}$$

Substituting figures

$$F = \frac{8 \times 5}{(8 + 5)\ (1.54 - 1)} = \frac{40}{7.02} = 5.7 \text{ inches}$$

Both surfaces are of the same nature and the focus is positive.

What is the focal distance of a lens with an index of refraction of 1.60 and its two surfaces having radii of minus 8 inches and plus 4 inches.

If one surface of the lens is convex and the other surface concave, the focus would be real or virtual according as the convex or the concave curvature was the greater.

We use the same formula as in the previous question:

$$F = \frac{-8 \times 4}{(-8 + 4)\ (1.60 - 1)} = \frac{-32}{-4 \times .60} = -13.3 \text{ inches}$$

This would mean a periscopic concave lens and the focus would be a negative one.

What would be the curvature of a meniscus lens on its concave surface if the convex surface had a curvature of 5 inches, its focal distance was at 12 inches, and its index of refraction was 1.60?

In order to ascertain the radius of curvature of one of the surfaces, when that of the other and the index of refraction and

the focal distance are known we can make use of the same formula, substituting the values of the known quantities and thus find the value of the unknown quantity,

$$12 = \frac{5r}{(5 + r)\ (.60)}$$

$$\text{or } 5\,r = 12\ (3 + .6\,r)$$
$$\text{or } 5\,r = 36 + 7.2\,r$$
$$\text{or } -2.2\,r = 36$$
$$\text{or } r = -16.36 \text{ inches}$$

What is the dioptric power or number of a lens whose radii of curvature are 10 cm. positive and 40 cm. negative, and the index of refraction 1.54?

In this case the formula is

$$D = \frac{100\ (\mu - 1)\ (r + r')}{r\,r'}$$

Substituting figures

$$D = \frac{(100 \times .54)\ (10 + (-40)\ )}{10 \times -40}$$

$$D = \frac{54 \times -30}{-400} = \frac{-1620}{-400}$$

$$D = +4.05 \text{ D.}$$

Find the dioptric number of power of a lens when the object is placed 50 cm. in front of it and the image 12.5 cm. behind it?

50 cm. represents a dioptric power of 2, and 12.5 cm. a dioptric power of 8, and the sum of the two represents the dioptric power of the whole lens, viz.,

$$8 + 2 = 10 \text{ D.}$$

Find the index of refraction of a periscopic lens whose focal distance was 24 cm., and its radii of curvature respectively + 6 and − 12 cm.?

$$24 = \frac{6 \times -12}{(6 - 12)\ (\mu - 1)} \text{ or } 24 = \frac{-72}{-6\,\mu + 6}$$

$$\text{or } -72 = -144\,\mu + 144 \text{ or } -216 = -144\,\mu$$

$$\text{or } 144\,\mu = 216 \text{ or } \mu = 1.50.$$

The index of refraction in this case is 1.50.

A parallel beam of light passes through a convex lens of 2 D., which is three inches in diameter; what is the shape and size of the patch of light it casts on a screen ten inches away?

This being a spherical lens the rays of light will be equally refracted in all meridians and will be brought to a focal point twenty inches from the lens. As it leaves the lens the patch of light will be circular in shape and the same size as the lens, that is three inches in diameter, and gradually lessens until it is contracted to a point at the focal distance. At a distance of ten inches, which is one-half the principal focal distance, it will have lessened one-half and form a circle of light one and a half inches in diameter.

A sphero-cylindrical lens + 5 D. S. = − 1.50 D. C. axis 90° is two inches in diameter. If a parallel beam of light passes through this lens, what is the shape and size of the patch of light it casts on a screen 15 cm. away?

In the vertical meridian the lens will have the full power of the sphere and will bring parallel rays of light to a focus at a distance of 20 cm.

In the horizontal meridian the power of the sphere will be reduced by the concave cylinder to + 3.50 D., thus causing parallel rays of light to meet in a focus at a distance of about 29 cm.

The light passing through the vertical meridian conveying to the focal point 20 cm. away, meets the screen at a distance of 15 cm., and as this is ¾ the distance from the lens, the patch of light will be lessened in the same proportion, that is to one-half inch.

The light passing through the horizontal meridian converging to a point 29 cm. away, meets the screen at 15 cm., which is 15/29 of the focal distance, and therefore the patch of light will be reduced to 14/29 of two inches, which is 28/29 of an inch.

The patch of light will be oval in shape, measuring one-half inch vertically and 28/29 of an inch horizontally.

If an object be held 100 cm. in front of a − 5 D. lens, what is the character and location of the image formed?

This is a problem referring to conjugate foci of concave lenses, which refract light with that degree of divergence as if the rays originated from the principal focal distance of the lens. In the case of the − 5 D. lens in the question, the rays would appear to diverge from a distance of 20 cm.

If the object is nearer than infinity, the rays from it striking the lens are divergent, but this divergence would be increased by the concave lens, and would make the light appear to originate from a point closer than the principal focal distance of the lens.

If D. represents the refractive power of the lens, and the distance of the object be expressed in diopters as d_1 and the distance of the image as d_2, then the formula is

$$D. = d_1 + d_2$$

In the case of a concave lens it must be remembered that the D. and d_2 are negative, and the formula would be

$$D. = d_1 + (- d_2)$$

or $d_2 = D. - d_1$.

Substituting the figures in the above question we have

$$d_2 = -5 - 1 = -6 \text{ D.}$$

And if d_2 represents a dioptric power of − 6 D., then the distance is 100/6 or − 16.66 cm., which means a virtual image 16.66 cm. in front of the lens.

If rays diverge from 100 cm. to a − 5 D. lens, after passing through the lens they are divergent as if they came from 16.66 cm.

What is the general formula for calculating the size of object or image, and give an illustration of it?

The relative sizes of object and image are proportional to their respective distances from the center of the lens, and this statement is true for the virtual images of both convex and concave lenses.

When the object is at twice the principal focal distance, the size of the image is the same; when it is farther away than twice the focal distance, the image is smaller; when the object is less than twice the focal distance, the image is larger.

Let f_1 represent the distance of the object, f_2 the distance of the image, h_1 the size of the object and h_2 the size of the image, then the proportions are

$$f_1 : f_2 :: h_1 : h_2$$

from which we get the following formula:

$$h_2 = \frac{h_1 \ f_2}{f_1}$$

This formula is applicable in all cases whether the image be real or virtual, and whether the lens be convex or concave.

For instance, if the size of the object be 1 inch and its distance 5 feet, and the image be at a distance of 5 inches, then

$$h_2 = \frac{1 \times 5}{60} = \frac{5}{60} = \frac{1}{12} \text{ in.}$$

The size of the image in this case is 1/12 inch.

Draw a diagram showing the construction of a real image by a convex lens.

In the construction of the image of an object formed by a convex lens, there are three rays which must be considered and followed:

1. The ray which passes through the optical center (O c), which is not refracted.

2. The ray which is parallel to the principal axis and which after refraction passes through F_2.

3. The ray which passes through F_1, and which after refraction runs parallel to the principal axis.

The second and third rays are the ones necessary to be drawn in order to locate the image of a point.

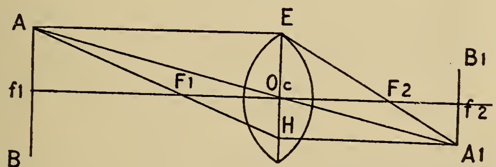


FIG. 10

In this diagram *A B* represents the object and *B′ A′* the inverted image.

Draw the principal axis from the object to the image through the optical center.

Draw line from *A* to *E* parallel to the axis. This line is then refracted and passes through F_2 extending to *A′*.

Draw line from A to H passing through F_1. This line after refraction is parallel to the axis and extends to A'.

Draw line from A to A' passing through the optical center.

The three lines originating from A meet at A', and therefore A' is the image of A.

In the same way B' can be constructed as the image of B, and then $B' A'$ represents the position and size of the real inverted image of the object $A\ B$.

If an object be placed 20 inches in front of a 6-inch convex lens, and it is desired to form the image at 10 inches, what power of lens must be added?

If it is desired to move the image from f_2 to some other position, say to a more distant position expressed as X, or a nearer position expressed as y, there must be added to the original lens another lens whose power would be the difference between

$$\frac{1}{X} \text{ and } \frac{1}{f_2}$$

or

$$\frac{1}{y} \text{ and } \frac{1}{f_2}$$

For instance, if f_2 be at 40 cm. and it is desired to move it to 50 cm., which is represented by x, then f_2 = 2.50 D. and X = 2 D. and the difference − .50 D., the necessary lens to be added is concave because x is more distant than f_2.

For instance, again, if f_2 is situated at 40 cm. and it is desired to bring it up to 20 cm., which is represented by y, then f_2 = 2.50 D. and y = 5 D., and the difference between the two is + 2.50 D., the necessary lens to be added must be convex because y is closer than f_2.

In the above question, in order to find the position of f_2, we must subtract 1/20 from 1/6 which equals 7/60, from which we must subtract 1/10 (the desired distance of image being 10 inches) and the result is 1/60. Therefore, as x is more distant than f_2 the necessary lens is a 60-inch concave to be added to the 6-inch convex.

Draw a diagram showing the construction of an image by a concave lens.

In this diagram $A\ B$ is an object in front of a concave lens, the principal focus of which is at F.

From A we draw a line to H, passing through the optical center of the lens.

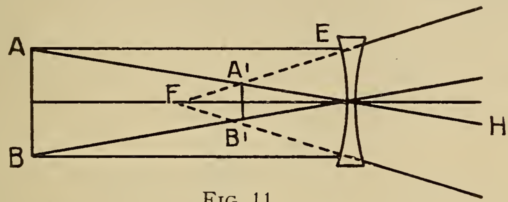


FIG. 11

Draw another line from A to E parallel to the axis, which after refraction is diverged as if it came from F.

These two lines being divergent can meet only when produced backward when they come together at A_1, which is the image of A.

Similar lines from B meet at B_1, which is the image of B.

Therefore, $A_1\ B_1$ is the complete image of the object $A\ B$.

How is the magnifying power of lenses expressed?

The absolute magnification of an object is expressed by the ratio between the angle subtended by the image at the eye and the angle subtended by the object at the eye.

If the former angle is represented by $A\ I$ and the latter by $A\ O$ then the magnification is expressed as follows:

$$\frac{A\ I}{A\ 0}$$

It may also be defined as the ratio between the size of the image and the size of the object on a comparison of both at the same distance from the eye.

The apparent magnification is the size of the object in comparison with that of the image at its point of most distinct vision.

It is more difficult to estimate magnification in relation to the eye than when the image is thrown upon a screen. In the latter case the image and the object can both be measured, and the first divided by the second will show the true magnification.

But in the case of the eye we are unable to determine magnification by so simple a method, for various reasons. The nearness of distinct vision varies in different persons; so also does the size of the retinal image vary with accommodation and

shape of the eye, and also the distance of the lens from the eye and from the object. And then besides there is a mental condition which affects the apparent relative size. If several persons were asked the size of the moon as it appears to them, they would probably all give a different estimate.

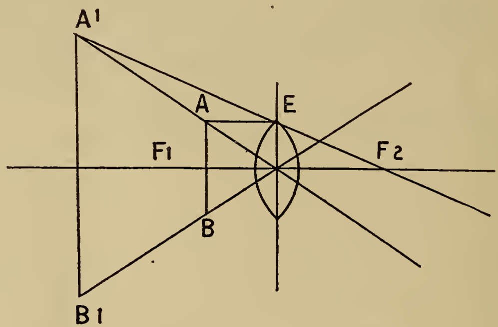


FIG. 12

If d represents the distance of most distinct vision, then the usual formula to express the magnifying power of the lens is

$$M = \frac{F + d}{F} \text{ or } \frac{d}{F} + 1$$

And as 10 inches is allowed for the distance of most distinct vision, for the average eye, we can substitute this figure and the formula will read

$$M = 1 + \frac{10}{F}$$

For lenses expressed in diopters, it would be

$$M = 1 + \frac{D}{4}$$

By way of illustration, if we use a 5-inch convex lens,

$$M = 1 + \frac{10}{5} = 3$$

Such 5-inch lens is equivalent to an 8 D. lens, with which

$$M = 1 + \frac{8}{4} = 3$$

Draw a diagram showing the construction of a virtual image by a convex lens.

Draw line from A to E parallel to the axis, which line after refraction will pass through F_2.

Draw another line from A passing through the optical center.

These two lines are divergent as regards each other and could not meet to form a real image; but by producing them backwards they will meet at A^1, which is the virtual image of A.

Similar lines from B would locate its virtual image at B_1, and hence A^1 B_1 is the complete virtual image of the object A B.

What is the effect produced by altering the position of a convex lens, and give several illustrations?

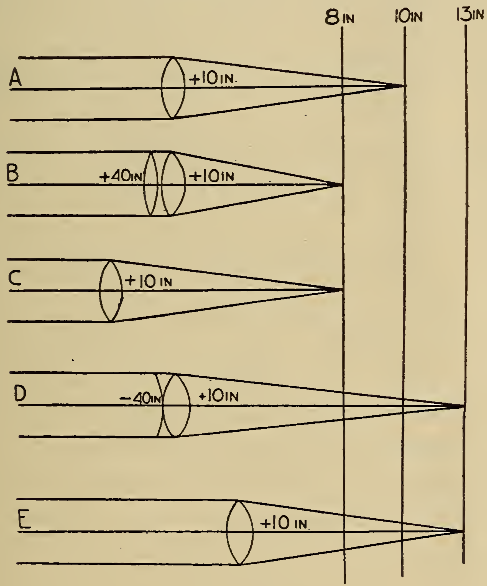


FIG. 13

The power of a convex lens is represented by $\frac{1}{F}$, which is the reciprocal of its principal focal distance. If the latter is 10 inches, the power is 1/10. It is self-evident that the power and focal distance are fixed quantities, but at the same time it is true that the power of the lens, in relation to a given point, varies with its distance from that point; that is, when a convex lens is moved away from a given plane, it acts with increased power as regards that plane, or in other words, like a lens of shorter focus.

And conversely, a convex lens loses in power as regards a certain plane when moved closer to it, or in other words, like a lens of longer focus.

Referring to diagram *A* in the illustrations below, it is seen that parallel rays of light entering a 10-inch convex lens are brought to a focus at a distance of 10 inches from the lens.

If a 40-inch convex lens is placed in contact with it as in diagram *B*, the two lenses will have a principal focal distance of

$$\frac{1}{10}+\frac{1}{40}=\frac{5}{40} \text{ or } \frac{1}{8}; \textit{ i. e.}, \text{ 8 inches}$$

and then the parallel rays will be brought to a focus at a distance of 8 inches. The same result will be obtained if the 10-inch lens is moved farther away, as in diagram *C*, thus proving that a convex lens acts with increased powers as it is moved farther away.

If a 40-inch concave lens is placed in contact with the 10-inch convex lens, the combined lenses will have a principal focal distance of

$$\frac{1}{10}-\frac{1}{40}=\frac{3}{40}, \text{ or } \frac{1}{13}; \textit{ i. e.}, \text{ 13 inches}$$

and then parallel rays will be focused at 13 inches, as shown n diagram *D*.

The same effect is produced if the 10-inch convex lens is moved closer, as in diagram *E*, thus proving that a convex lens acts with diminished power as it is moved closer.

If $\frac{1}{F}$ represents the power of a convex lens, and d the given distance which it is moved, then its power would be

$$\frac{1}{F - d}$$

Using the figures in diagrams *A*, *B* and *C*,

$$\frac{1}{10 - 2}=\frac{1}{8}$$

The shorter distance represents a stronger lens.

If a convex lens be moved to a greater distance than its principal focus, not only will its converging power be neutralized, but it will have the effect of a concave lens. If this 10-inch convex lens be moved to 13 inches from a screen, the rays will meet at 10 inches, that is 3 inches in front of the screen, and

striking the screen with this divergence will have the effect of a three-inch concave lens, as follows:

$$\frac{1}{10 - 13} = -\frac{1}{3}; \text{ } i.\ e., \text{ 3 inches negative}$$

What is the effect produced by altering the position of a concave lens, and give several illustrations?

When a concave lens is moved farther away from a point back of the lens, its power is decreased and it acts as a lens with a longer focus.

If a concave lens is moved closer, its power is increased, and it acts as a lens with a shorter focus.

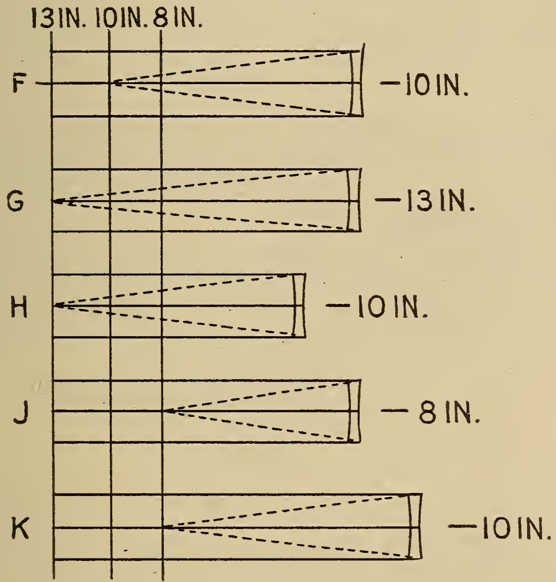


Fig. 14

When parallel rays of light pass through a 10-inch concave lens, they will be diverged as if they came from a point 10 inches in front of the lens, as shown in diagram *F*.

If a 13-inch concave lens is made use of, the negative focus would be 13 inches in front of the lens, as shown in digram *G*.

But the same effect can be produced by moving the 10-inch concave lens front 3 inches, as shown in diagram *H*, where the effect of the 10-inch lens is reduced to that of the 13-inch lens,

thus proving that the power of a concave lens is decreased by moving it away from a given point back of the lens.

If an 8-inch concave lens be used the negative focus will be at 8 inches, as shown in diagram *J*.

But the same effect can be produced by moving the 10-inch lens back 2 inches, as shown in diagram *K*, where the effect of the 10-inch lens is increased to that of the 8-inch lens, thus proving that the power of a concave lens is increased by moving it closer to a given point back of the lens.

What is the effect produced by two convex lenses when they are separated from each other? Give an example.

The combined power of two lenses when placed close together is equal to the sum of the power of each, just as simply as $2 + 2 = 4$.

But if the two lenses are not in actual contact, that is, if they are appreciably separated, the resultant effect will not be the same as when they are together, which fact is easy of demonstration by a drawing.

Parallel rays of light striking the first lens, which is a 16-inch convex lens, will be converged so as to meet at the point *A*, which is 16 inches behind it.

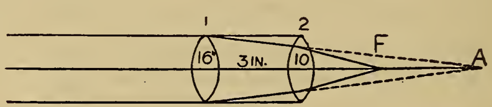


FIG. 15

But on their way when 3 inches from the first lens, they meet the second lens, which is a 10-inch convex lens, and if they would still meet at the point *A*, they are now converging to a point 13 inches (16 − 3) behind the second lens.

Therefore, the power of the first lens at the position of the second lens, is increased from 1/16 to 1/13, which means that the resultant effect will be the same as if a 13-inch lens was placed in contact with the second lens, and the combined power of the two lenses as separated will be

$$\frac{1}{13} + \frac{1}{10} = \frac{1}{5.6} \quad \text{instead of} \quad \frac{1}{16} + \frac{1}{10} = \frac{1}{6}$$

as it would be if the lenses were close together.

If F_1 represents the front lens and F_2 the back lens, and d the distance between them, and F the focal distance of the combination, then the formula for finding F would be

$$\frac{1}{F_1 - d} + \frac{1}{F_2} = \frac{1}{F}$$

Substituting the figures in the above example:

$$\frac{1}{(16-3)} + \frac{1}{10} = \frac{1}{5.6}$$

The distance of F would differ considerably if these lenses were reversed and the 10-inch lens faced the light, and the 16-inch lens was 3 inches behind it. When so arranged, according to the formula given above, the result would be

$$\frac{1}{10-3} + \frac{1}{16} = \frac{1}{4.8}$$

What is the effect of two concave lenses when they are separated from each other? Give an example.

If the two lenses are close together their combined power would be equal to the sum of their individual powers, as for instance, if a − 2 D. lens was placed against a − 3 D. lens, the combined power would be equal to − 5 D. But if the lenses are separated the resultant effect will not be the same.

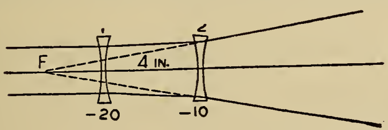


FIG. 16

Parallel rays of light striking the first lens, which is a 20-inch concave lens, will be diverged as if they came from a point 20 inches in front of the lens.

After traveling 4 inches the rays meet the second lens, which is 24 inches from the negative focus of the first. Therefore, we have a divergence of 1/24 added to a divergence of 1/10 (which represents the negative power of the second lens, a 10-inch concave), which equals a total divergence of 1/7.

Using the formula previously given:

$$\frac{1}{-20-4} + \frac{1}{-10} = -\frac{1}{7}$$

If an object be placed 40 inches in front of a 16-inch lens convex, and 4 inches behind which a 26-inch concave lens is placed, where will the image be formed?

When light, falling upon a lens, is divergent instead of parallel, the conjugate focus must be found before we can make use of our formula.

In this case, where rays diverge from a point 40 inches in front of the lens, which is a 16-inch convex, the conjugate focus would be

$$\frac{1}{16} - \frac{1}{40} = \frac{3}{80}, \text{ or } \frac{1}{27}$$

that is at 27 inches.

Then we have

$$\frac{1}{27-4} + \left(-\frac{1}{26}\right) = \frac{1}{199}$$

Therefore, the image is at 199 inches.

What is the effect of a convex and a concave lens when separated? Give several examples.

When a convex and a concave lens of equal power are placed in contact, there is neutralization and parallel rays would pass unrefracted, but if the lenses are separated, one or the other will predominate, as the case may be.

If the distance between the lenses is less than the focal length of the first or convex lens, the combination will be a positive one; if the distance between the lenses exceeds the focal distance of the first lens, then the combination will be negative.

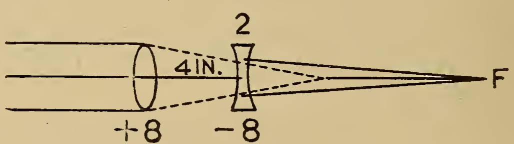


Fig. 17

Parallel rays of light striking the first lens, which is an 8-inch convex, will be converged so as to meet in focus at a point 8 inches away. But after having traveled 4 inches, they meet the concave lens of 8 inches, and at that point they have a convergence of $+\frac{1}{4}$, which is partly overcome by the 1/8 divergence of

the concave lens, causing the rays to meet at a point 8 inches back of the second lens.

Using the proper formula

$$\frac{1}{8-4} + \left(-\frac{1}{8}\right) = +\frac{1}{8}$$

which means a positive focus at 8 inches.

If, instead of a convex and concave lenses being of equal focal length, the concave be the shorter, and then when placed in contact, the concave lens will predominate and no real image can be formed.

If now, the convex lens be moved forward towards the light, it will increase in power until the point is reached where the separation is equal to the sum of their focal lengths, and then neutralization will occur and the rays will issue parallel.

If the convex lens is moved still closer to the light, it predominates, increasing until the separation equals the focal distance of the convex lens, when it is at its maximum.

In the separation of a convex and a concave lens, the result will be different as the light strikes first the convex or the concave.

In the above illustration, where an 8-inch convex lens was 4 inches in front of an 8-inch concave lens, we found that *F* was at 8 inches.

But if the first lens was the concave one, then the result would be

$$\frac{1}{-8-4} + \frac{1}{8} = +\frac{1}{24}$$

that is *F* would be at 24 inches. And from this we learn that *F* is closer when the convex lens is nearer the light, and farther away when the concave lens is nearest the light.

If an object be placed 80 inches in front of a 14-inch convex lens, where must a 10-inch concave lens be placed so as to render the rays parallel?

When the rays of light instead of being parallel are divergent when they enter the lens, as in this case, we must find the conjugate focus before the value of *d* (representing the distance between the lenses) can be applied to the front lens of the combination.

It will be remembered that the formula for conjugate foci was

$$\frac{1}{F} - \frac{1}{f_1} = \frac{1}{f_2}$$

Substituting the figures in this question we have

$$\frac{1}{14} - \frac{1}{80} = \frac{66}{1120} \text{ or } \frac{1}{17}$$

The image is 17 inches back of the 14-inch convex lens.

And in order to find where the 10-inch concave lens must be placed to secure parallelism, we have

$$17 - 10 = 7 \text{ inches,}$$

it must be placed 7 inches back of the convex lens.

When the light leaves the convex lens the rays are converging to a point 17 inches away; but at a distance of 7 inches from the lens they are converging to a point 10 inches away, and at this position a concave lens of 10 inches would render the rays parallel. Or in other words, the convergence to 10 inches of the convex lens would be neutralized by a divergence of 10 inches of the concave lens.

What must be the distance between a 10-inch convex lens and a 4-inch concave lens, in order to produce the effect of a 40-inch convex lens?

It will be remembered that the formula in such a case is

$$F = \frac{(F_1 - d)\, F_2}{F_1 + F_2 - d}$$

When we come to substitute the figures in the question, we find we have figures for all the quantities except the distance; hence, we must write it as follows:

$$+ 40 = \frac{(10 - d) - 4}{10 - 4 - d}$$

$$\text{or } + 40 = \frac{- 40 + 4\, d}{6 - d}$$

For those who are not thoroughly familiar with algebra we would say that when we multiply + 10 by − 4 the result is − 40, and when we multiply − d by − 4 the result is + 4 d, which gives the new numerator.

And for the denominator we add + 10 and − 4 and the result is + 6. It might be remarked here that when no sign is placed in front of a number, it is understood to be a plus.

Now, in order to get rid of the fraction we must multiply the above equation by 6 − d, and the result will be

$$240 - 40\ d = -40 + 4\ d$$

Now, we must get the d's on one side of the equation and the numbers on the other side, and then we have

$$-44\ d = -280$$

$$d = 6\tfrac{4}{11}$$

When a plus number is carried to the other side of the equation it becomes a minus, and when a minus number is carried over it becomes a plus.

Now, in order to verify the result we can use the formula again as follows:

$$\frac{(10 - 6\frac{4}{11}) - 4}{+10 - 4 - 6\frac{4}{11}} = 40$$

$$\text{or}\quad \frac{3\frac{7}{11} \times (-4)}{-\frac{4}{11}} = \frac{-\frac{160}{11}}{-\frac{4}{11}} = 40$$

Therefore, the distance between the 10-inch convex lens and the 4-inch concave lens must be $6\frac{4}{11}$ inches in order to produce the effect of a forty-inch convex lens.

A point of light is situated two meters from a + 2 D. spherical lens; at what distance will the image be formed?

If the lens is the same number concave, where and what will be the image? The rays proceeding from the light at a distance of two meters would enter the lens with a divergence of .50 D. and, therefore, the lens would be reduced by that much to make the rays parallel. In other words, inasmuch as .50 D. of the power of the lens is used up to take care of the entering rays, there would be only 1.50 D. left to act on the emerging rays, which would bring the light to a focus at two-thirds of a meter on the opposite side of the lens from the light.

If these rays with a divergence of .50 D. enter a concave lens, their divergence would be increased by the amount of divergent power of the lens, and in this case the rays would emerge from this lens with a divergence of 2.50 D., which would indicate a

negative focus of two-fifths of a meter on the same side of the lens as the light.

A + 3 D. spherical lens forms an image of a light at a distance of 50 cm. on the opposite side of the lens from the object; at what distance is the light from the image?

If the image was at a distance of 50 cm. from the lens on the same side as the light, what would be the distance between the object and the image?

A + 3 D. lens would bring parallel rays to a focus at 33 cm., but if the image is formed at a distance of 50 cm. it must be that the rays that enter the lens are divergent instead of parallel, and the amount of divergence would be represented by the difference between 3 D. and 2 D., this latter corresponding to the divergence of the rays from the image at a distance of 50 cm. The result is 1 D., which means a distance of 100 cm. as the location of the light from the lens; or a distance of 150 cm. from object to image.

If the image was at a distance of 50 cm. from the lens on the same side as the light, this would mean the virtual image of a convex lens, due to the fact that the object was closer to the lens than its principal focal distance.

This negative focal distance of 50 cm. indicates a divergence of 2 D. and if this amount remained after passing through a + 3 D., the original divergence must have been 5 D., corresponding to a distance of 20 cm. as the position of the object.

And if the distance of the object is 20 cm. and of the image 50 cm. on the same side of the lens, the distance between object and image must be 30 cm.

An image of a distant point of light is formed on a screen by means of a convex spherical lens. If the lens is tilted so that it is inclined at an angle of 45 degrees to the direction of the incident rays, there are two positions of the screen, as it is moved closer to and farther from the light, in which the image takes the form of a luminous straight line at right angles to each other in the two positions. What is the explanation?

When a spherical lens is held obliquely to incident rays of light, and added cylindrical effect is produced, and it acts as a

sphero-cylindrical lens. If the spherical lens be held at its focal distance from the screen and parallel to it, a perfect image of a distant point of light is formed upon the screen; but if the lens be held obliquely the image is distorted and elongated as if a cylinder had been added to the sphere. Two bright focal lines are formed on the screen at right angles to each other when the lens is held at the proper distance for each.

The obliquity of the lens increases the refractive power of both meridians, but more decidedly so in the meridian at right angles to the axis of rotation. Therefore, the effect produced is that of a slightly stronger sphere combined with a cylinder whose axis would correspond to the axis of rotation. In like manner rotation of a cylindrical lens around its axis causes increased effect in the meridian at right angles thereto.

If a convex sphere be held upright and parallel to a screen, it will form a circular image of a point of light that is on a level with the axis of the lens; but if the lens be tilted around a horizontal axis, it will no longer form a circular image, but will produce two ill-defined lines, one vertical a little closer than the original focus, and another horizontal much nearer the lens; the latter as a result of the increase of power in the meridian of rotation. This increase of power is due to the fact that the light passes through a greater thickness of glass when the lens is oblique than when it is in its proper position.

If a + 1 D. sphere be rotated 45°, the approximate effect produced would be

$$+ 1.20 \text{ D. S.} \bigcirc + 1.20 \text{ D. cyl.}$$

which would show a focal line in one meridian at 83 cm. and in the other meridian at 42 cm.

An object is held 80 inches in front of two lenses, the first of which is a 14-inch convex and the second is a 10-inch concave. It is desired to focus the image 40 inches behind the concave lens; what must be the distance between the two lenses to accomplish this?

As the object is only 80 inches in front of the convex lens, the rays will enter it divergently and the image will be formed not at the principal focal distance of the lens (which is the focus for parallel rays), but at some farther distance. This distance

can be found by the formula for conjugate foci, as follows:

$$\frac{1}{14} - \frac{1}{80} = \frac{66}{1120} \text{ or about } \frac{1}{17}$$

Therefore, the power of the lens has been reduced to that of a 17-inch convex lens.

Making use of the formula for the effectivity of two lenses when separated, and substituting the above figures we have

$$40 = \frac{(17 - d) - 10}{17 + (-10) - d}$$

For the numerator we multiply 17 − d by − 10, and for the denominator we collect and simplify. The result is

$$40 = \frac{-170 + 10\,d}{7 - d}$$

In order to get rid of fractions we multiply by 7 − d, and then the equation will read

$$280 - 40\,d = -170 + 10\,d$$

Collect the d's on one side and the numbers on the other:

$$-50\,d = -450$$

$$d = 9$$

In order to produce the desired result the interval between the convex and the concave lens must be 9 inches.

An object is placed 60 inches in front of two convex lenses, the first of which is a 30-inch lens and the second is a 40-inch lens; what must be the distance between the two lenses in order that the image shall be formed 10 inches behind the second lens?

As the rays strike and enter the first convex lens with a divergence of 1/60, the power of the lens is practically reduced by that much, as follows:

$$\frac{1}{30} - \frac{1}{60} = \frac{1}{60}$$

We now have a 60-inch convex lens and a 40-inch convex lens, and by making use of the formula given in the previous question we have

$$10 = \frac{(60 - d)\,40}{60 + 40 - d} \qquad \text{or } 1000—10\,d = 2400—40\,d$$

$$\text{or } 10 = \frac{2400 - 40\,d}{100 - d} \qquad 30\,d = 1400$$

$$d = 46\ 2/3$$

These two convex lenses must be separated by a distance of $46\frac{2}{3}$ inches to accomplish the result desired.

What does a compound microscope consist of? Give a brief description of it.

The compound microscope is used to obtain a magnified view of small objects close at hand. It consists of two convex lenses which are separated from each other, the amount of separation being dependent upon the length of the instrument.

The first lens is called the objective; it should be corrected for aberrations, and forms a real magnified and inverted image of an object, which should be placed just beyond its principal focal distance.

The second lens is called the eye lens, or eyepiece, or ocular; not quite so strong as the first, by the aid of which the image is viewed.

If S. O. represents size of object, D. O. its distance from the microscope and D. I. the distance of the image from the objective, then the size of the image will be equal to

$$\frac{\text{D. I.} \times \text{S. O.}}{\text{D. O.}}$$

The magnification can be increased by a greater separation between the two lenses, which would increase D. I. Also by bringing the object closer to the microscope, which would decrease D. O.

If the image formed by the objective is located at the principal focal distance of the eyepiece, the rays would be parallel, the object would seem to be at infinity and there would be no strain on the eye of the observer.

The small object just beyond the focal distance of the objective lens, forms a real image of the object, which image is inverted and magnified. When the eye of the observer is behind the eyepiece, there is seen at the distance of most distinct vision a more magnified image of the object, which is still inverted and is now virtual instead of real as formed by the objective.

What does an opera glass consist of? Give a brief description of it.

An opera glass consists of a convex lens and a concave lens of higher power. When the convex lens is placed in front of the concave lens at a distance that is equal to the algebraic sum of their focal lengths, the lenses neutralize each other by their separation. If F_1 represents the focal length of the first or convex lens, and F_2 the focal length of the second or concave lens, then the amount of separation is equal to F_1 plus F_2, and this is the way the glasses should be separated for an emmetrope.

In the case of hypermetropia where the light should enter the eye in convergent rays in order to focus on the retina, the separation of the lenses should be a little greater; while in myopia where the light should enter the eye in divergent rays, in order that vision may be clear, the distance between the lenses should be less.

Although the rays of each pencil emerge parallel or divergent from a very distant point after refraction by the two lenses, yet the pencils themselves are deviated so that the object appears under a larger angle.

The magnification produced by an opera glass can be expressed by the fraction

$$\frac{F_1}{F_2}$$

If the focal length of the first convex lens was 5 inches and if the second concave lens was 2 inches, the magnifying power is

$$\frac{5}{2} = 2\tfrac{1}{2}$$

If the position of the lenses was reversed and the concave lens was placed in front, then the object viewed would appear diminished in size in the same ratio, which in this case would be

$$\frac{2}{5}$$

that is the minification would be $2\frac{1}{2}$ times.

What does a stereoscope consist of? Give a brief description of it.

The stereoscope is a box or frame fitted at one end with two sphero-prisms bases out (which are really the transposed halves of one large convex lens), and at the other end there is a slide that carries two photographs.

These photographs are taken from slightly different standpoints, usually about 2½ inches apart, which correspond to the average pupillary distance, but which may be varied for the degree of stereoscopic effect desired.

On a casual glance the photographs look alike, but they are really dissimilar, the right one corresponding to the image formed in the right eye and the left one to the image formed in the left eye.

As the action of a prism is to cause an apparent displacement in the direction of its apex, the lenses of the stereoscope cause the apparent position of each photograph to be displaced inwards with the result of fusing the two into one, and that without any muscular effort on the part of the eyes. The single image that is produced is virtual and located near the point of most distinct vision of the observer.

This instrument artificially produces the appearance of solidity and perspective that naturally results from binocular vision. This effect is given to flat pictures, because each eye obtains a view identical with what they would receive when viewing the objects directly.

The distance between the prisms and the photographs is equal to the focal distance of the spherical lenses, and therefore an emmetrope will need to use neither accommodation or convergence. If hypermetropia or myopia is present, the distance will have to be altered accordingly.

What does a telescope consist of? Give a brief description of it.

The telescope is used to obtain an enlarged view of distant objects, and in its simplest form consists of two convex lenses, the weakest of which is called the object glass or objective, and is turned toward the distant object that is to be viewed; while the stronger is called the eyepiece or eye lens and it is placed immediately in front of the eye. Both of these lenses should be corrected for spherical and chromatic aberration.

A real inverted image of a distant object is formed by the objective, and this image as seen through the eyepiece is a virtual one, subtending an angle greater than that of the object, and it is upon the ratio between these two angles that the magnification depends.

Since the object looked at is a distant one, the rays proceeding from it are parallel, and hence the image formed by the objective will be at its principal focal distance. If it is desired that in an emmetrope the image be seen by the eye without accommodation, its location must coincide with the principal focal distance of the eyepiece.

In other words, the parallel rays are converged by the objective to a focus from which they diverge to the eyepiece, which parallels them, so that they can be focused in the emmetropic eye without accommodation. Therefore, the distance between the lenses must be equal to their focal lengths.

The magnification produced by a telescope when adjusted to suit an emmetropic eye without accommodation is equal to $\frac{F_1}{F_2}$, where F_1 represents the focus of the objective and F_2 the focus of the eye lens.

In the case of a hypermetrope the telescope would be adjusted so that the distance between the two lenses would be greater than their focal lengths, under which circumstances the rays would enter the eyepiece diverging from a point greater than its focal distance, and hence would leave the lens and enter the hypermetropic eye as convergent rays and thus be focused on its retina.

In the case of a myope, the telescope would be adjusted so as to lessen the distance between the lenses, and then the rays would enter the eyepiece diverging from a point closer than its focal distance, and hence would leave the rays and as such would be focused on its retina.

To obtain high magnification, the focal distance of the objective must be as great, and of the eyepiece as short, as possible; for this reason in a telescope the objective must be a lens of long focus and the eyepiece a lens of short focus.

The image as seen by the eye is inverted, but with respect to heavenly bodies this is a matter of no importance. If so desired, this inversion can be overcome by means of an erecting eyepiece, which causes a reinversion of the image, the objection to which, however, is that there is a loss of light owing to the increase of the refracting surfaces.

How can you determine the position and magnitude of an image of an object placed in front of a convex lens? An arrow 5

inches long is placed 8 inches away from a convex lens whose focal length is 3 inches. Find the position and length of the image.

First we must find the position of the image. As the arrow is at a distance of 8 inches, the rays proceeding from it would enter the convex lens of 3 inches focal length, with a divergence of 1/8. After this divergence is overcome there would remain in the lens a convergence power of $\frac{1}{4\frac{4}{5}}$, which is found as follows:

$$\frac{1}{3} - \frac{1}{8} = \frac{5}{24} = \frac{1}{4\frac{4}{5}}$$

Therefore, the position of the image would be 4 4/5 inches from the lens. In order to find the length of the image we have this proportion; the distance of the object is to the size of the object as the distance of the image is to the size of the image.

Substituting figures we have

$$8 : 5 :: 4\tfrac{4}{5} : X$$

$$X = \frac{5 \times 4\frac{4}{5}}{8} = \frac{24}{8} = 3$$

Therefore, the length of the image is 3 inches.

An incandescent gas light, with a mantle 10 centimeters high, stands at the same level as a converging lens, the power of which is 5 D., situated 6 meters to the right of the light. Find the position and the size of the image of the mantle. If the light is then lifted up 1 meter above its former position, what change will take place in the position of the image?

Ordinarily, in the practice of optometry, we make our tests of the acuteness of vision at a distance of 6 meters, on the assumption that rays proceeding from this distance are practically parallel. But, as a matter of fact, these rays have a slight divergence.

Six meters equal 600 centimeters, and the amount of divergence would be found by dividing 600 into 100, which would be 0.17 D. This would reduce the power of the plus 5 D. lens to plus 4.83 D.

The focal distance is found by dividing 4.83 into 100, and the result is 20.7 centimeters, which would be the position of the image.

The length of the image is found by using the proportion as in the previous question:

$$600 \text{ cm.} : 10 \text{ cm.} :: 20.7 \text{ cm.} : X$$

$$X = \frac{10 \text{ cm.} \times 20.7 \text{ cm.}}{600 \text{ cm.}}$$

$$X = \frac{207 \text{ cm.}}{600 \text{ cm.}} = 0.345 \text{ cm.}$$

The length of the image is 0.345 cm.

As the light is elevated the image would be correspondingly depressed. If the light is lifted one meter, which is one-sixth the distance of the object, the image would be lowered in the same proportion, that is, one-sixth the distance of the image (1/6 of 20.7 cm.), which is 3.4 cm.

If the refractive index from air to glass is 3/2, and that from air to water is 4/3, what is the ratio of the focal lengths of a glass lens in water and in air?

This is equivalent to saying that when light passes from air into glass it is subject to an index of refraction of 1.50, and when it passes from air into water it is subject to an index of 1.33, but when it passes from water into glass the conditions are different.

The index of refraction from one medium to another is equal to the refractive index of the latter divided by that of the former. For all practical purposes we assume air to be the unit, and if the index of refraction from vacuum to glass is 1.52, or as we ordinarily say, the index of refraction of glass is 1.52, then the index of refraction from air to glass is 1.52/1, or 1.52.

The relative index of refraction is the expression of the refractivity when light passes from one dense medium into another dense medium, as from water into glass or glass into water. According to the rule mentioned above, this relative index is found by dividing the index of the medium into which the light passes, by the index of the medium from which it proceeds.

In this question where the light passes into glass with an index of 3/2 or 1.50 from water, with an index 4/3 or 1.33, the

relative index is found by dividing 3/2 by 4/3, and the result is 9/8 or 1.125.

Therefore, as the refractive index from air to glass is 3/2 or 1.50, and from water to glass is 9/8 or 1.125, the refractive index of the glass lens in water is reduced from 1.50 to 1.125, the latter being one-fourth of the former; then the focal length of the lens in water would be four times its length in air.

A convex and a concave lens, each 10 inches in focal length, are held co-axially at a distance of 3 inches apart. Find the position of the image if the object is at a distance of 15 inches beyond the convex lens, and also the position if the lenses were reversed and the concave lens was first.

If the object was at infinity the focal distance of the convex lens would be at 10 inches, but inasmuch as the rays enter the lens divergently from a point 15 inches away, the focus of the lens would be

$$\frac{1}{10} - \frac{1}{15} = \frac{1}{30} \text{ or at 30 inches.}$$

The formula is: $\dfrac{1}{F_1 - d} + \dfrac{1}{F_2} = \dfrac{1}{F}$

Substituting figures

$$\frac{1}{30 - 3} + - \frac{1}{10} = \frac{1}{27} - \frac{1}{10} = \frac{17}{270} = \frac{1}{16}$$

or 16 inches from the concave lens.

There would be considerable difference in the result if the concave lens was in front, as follows:

If parallel rays entered the 10-inch concave lens, its negative focus would be 10 inches; but, inasmuch as the rays entered the lens with a divergence of 1/15 the effective focus of the concave lens would be

$$-\frac{1}{10} - \frac{1}{15} = \frac{5}{30} = \frac{1}{6}$$

Using the formula we have

$$\frac{1}{-6-3} + \frac{1}{10} = -\frac{1}{9} + \frac{1}{10} = \frac{1}{90}$$

or 90 inches from the concave lens.

What is meant by the focal length of a spherical reflecting surface? How far from a concave mirror of radius 3 feet would you place an object to give an image magnified three times? Would the image be real or virtual?

Parallel rays striking a concave mirror are reflected in such a way as to converge to a point on the axis of the mirror, which is called the principal focus of the mirror.

If the mirror be convex the rays are reflected in such a way as to appear to diverge from a point on the axis behind the mirror, which is the principal focus of the convex mirror.

The distance from the mirror of the point to which parallel rays converge after reflection, or from which they seem to diverge, is called the focal length of the mirror.

The focal length of a mirror, whether convex or concave, is equal to one-half the radius.

In this question where the radius of the concave mirror is said to be 3 feet or 36 inches, the focal length would be 1½ feet or 18 inches.

The magnification is the ratio of the distance of the image from the mirror to the distance of the object from the mirror. Now, then, in order that the image may be magnified three times (and this magnification refers to linear dimensions and not to area), its distance must be three times that of the object, and in this question the focal distance of the object and the focal distance of the image must equal the focal length of the mirror, which is 18 inches.

$$\text{Let } X = \text{distance of image}$$
$$3X = \text{distance of object}$$
$$\text{Then } 4X = \frac{1}{18}$$
$$X = \frac{1}{72}$$
$$3X = \frac{3}{72} \text{ or } \frac{1}{24}$$

The distance of the object would be 24 inches of the image 72 inches.

And, inasmuch as the object is situated farther away than the focal distance of the mirror, the image would be real.

A bright object 4 inches high is placed on the principal axis of a concave spherical mirror, at a distance of 15 inches from the

mirror; what is the position and size of the image, the focal length of the mirror being 6 inches?

The first thing is to determine the position of the image, as follows:

$$\frac{1}{6} - \frac{1}{15} = \frac{9}{90} = \frac{1}{10}$$

The image is located at 10 inches.

Now, then, the distance of the object is to the size of the object as the distance of the image is to its size.

The first three factors being known, the fourth is determined by the following proportion:

$$15 : 4 :: 10 : \times$$

$$\times = \frac{4 \times 10}{15} = \frac{40}{15} = 2\tfrac{2}{3}$$

The size of the image is 2 2/3 inches.

What is the size and position of the image of an object 1 inch high placed respectively at distances of 6 inches, 9 inches, 1 foot, and 18 inches from a concave mirror 9 inches in radius?

If the radius of the mirror is 9 inches, its principal focal distance is 4½ inches.

If the object is at 6 inches, the image will be at

$$\frac{1}{4\frac{1}{2}} - \frac{1}{6} = \frac{1}{18} \text{ or 18 inches}$$

Then, as the distance of the image (18 inches) is three times the distance of the object (6 inches), the size of the image will be three times the size of the object or 3 inches.

If the object is at 9 inches,

$$\frac{1}{4\frac{1}{2}} - \frac{1}{9} = \frac{1}{9}$$

the image will be at 9 inches.

And in this case, as the distance of the image is the same as the distance of the object, the size of the image will be the same as the size of the object, viz., 1 inch.

If the object is at 12 inches,

$$\frac{1}{4\frac{1}{2}} - \frac{1}{12} = \frac{1}{7\frac{1}{5}}$$

the image will be at 7 1/5 inches.

The size of the image is found by the following proportion:

$$12 : 1 :: 7\ 1/5 : \times$$

$$\times = \frac{1 \times 7\frac{1}{5}}{12} = \frac{3}{5}$$

The size of image is 3/5 of an inch.

If the object is at 18 inches,

$$\frac{1}{4\frac{1}{2}} - \frac{1}{18} = \frac{3}{18} = \frac{1}{6}$$

the image will be at 6 inches.

And as the distance of the image (6 inches) is one-third the distance of the object (18 inches), the size of the image will be one-third the size of the object, or one-third of an inch.

What is the difference between conjugate foci that are interchangeable and those that are not? Give examples of each.

Conjugate foci are two points so related to each other that when the object is at the one, the image is at the other.

If F be the principal focal distance of a mirror, f_1 the distance of the object and f_2 the distance of the image, then

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\text{or } \frac{1}{F} - \frac{1}{f_1} = \frac{1}{f_2}$$

This is an important formula in optics; and f_1 and f_2 are conjugate to each other and are interchangeable. If any two are known, the third can always be found.

Suppose the focal length of the mirror be 8 inches, and the object be placed at a distance of 40 inches, then 1/8 would represent the reflecting power of the mirror, and 1/40 the power which brings parallel rays to a focus at a distance of 40 inches. Then

$$\frac{1}{8} - \frac{1}{40} = \frac{4}{40} \text{ or } \frac{1}{10}$$

And f_2 would be 10 inches from the mirror.

Therefore, 40 inches and 10 inches are the distances of the conjugate foci of this 8-inch concave mirror. If the object be placed at 40 inches, the image will be formed at 10 inches, and

if the object be placed at 10 inches, the image will be formed at 40 inches.

In the above case where the conjugate foci are interchangeable, the object is placed at a greater distance than the focal length of the mirror; but if the object be placed closer than the focal distance of the mirror, the conjugate focus is a negative quantity.

For instance, if we take this same 8-inch mirror and place the object 5 inches in front of it, then we have

$$\frac{1}{8} - \frac{1}{5} = -\frac{3}{40} \text{ or } -\frac{1}{13}$$

That is the image (if one could be formed) would be 13 inches behind the mirror.

We can prove this by the formula

$$\frac{1}{f_1} + \frac{1}{f_1} = \frac{1}{F}$$

Substituting figures

$$\frac{1}{5} + \left(-\frac{1}{13}\right) = \frac{1}{8}$$

Here − 13 inches (but not 13 inches) is conjugate to 5 inches with respect to an 8-inch concave mirror, and 5 inches is conjugate to − 13 inches, but not to 13 inches.

What are the laws of conjugate foci as they pertain to refracting systems?

1. In order that the object and image may be interchangeable, the rays of light must follow the same path in both directions.

2. If the object is moved to the right, the image moves to the right also; or in other words, the two foci, representing the object and image, always move in the same direction. (In the case of mirrors where the image is formed by reflection, the two foci move in opposite directions.)

3. If the rays proceed from a point farther away than the principal focus of the lens, they will be converged and the image be formed at the opposite side of the lens, and will be real and inverted.

4. If the rays proceed from a point closer than the principal focus, they will be diverged as if proceeding from an object

on the same side of the lens, and the image will be virtual and erect.

When parallel rays enter a convex lens and are converged, we say infinity and the principal focus are conjugate.

Does a convex lens ever produce a virtual image? If so, under what conditions?

When an object is placed closer to a lens than its principal focal distance, the divergence of the rays is so great that the lens is unable to overcome it, and the rays, after passing through the lens, would continue divergently. There would be no real focus, but a negative or virtual one, which could be found by drawing imaginary lines from the divergent rays backward to a point on the same side of the lens from which they appear to come.

For instance, if an object was placed 10 inches from a 20-inch lens, the rays would enter the lens with a divergence of 1/10, which would be partly neutralized by 1/20, the full power of the lens, and they would continue with a divergence of 1/20, or as if they came from a point 20 inches back of the lens. Under such conditions a convex lens produces a virtual image.

What are the laws of reflection of light? The radius of a concave mirror is 6 feet, and a circular disk 1 inch in diameter is placed on the axis of the mirror at a distance of 2 feet from it. Determine the size and position of the image.

The laws of reflection are:

1. The angle of incidence and the angle of reflection are the same; that is, the angle formed by the incident ray with the perpendicular is equal to the angle formed by the reflected ray with the perpendicular.

2. The incident and the reflected rays lie in the same plane.

These laws are true whatever be the form of the surface, whether plane or curved. Spherical mirrors may be concave or hollow toward the light, and convex or bulging toward the light.

In regard to a concave mirror, if the object be placed at its principal focal distance, the rays are reflected as parallel and hence no image is formed.

When the object is located beyond the focal distance of the mirror, the image is real; and when object is inside of the focal distance, the image is virtual.

In order to find the position of the image, we must make use of the formula for conjugate foci. If the radius of the mirror is 6 feet, the principal focus must be 3 feet, or 36 inches.

If F is principal focus, f_1 is distance of object, and f_2 is distance of image, then

$$\frac{1}{F} - \frac{1}{f_1} = \frac{1}{f_2}$$

Substituting figures

$$\frac{1}{36} - \frac{1}{24} = \frac{1}{72}$$

or 72 inches, or 6 feet.

Inasmuch as the size of the image must be to the size of the object as the distance of the image is to the distance of the object, and as the image is at 6 feet and the object at 2 feet, or three times the distance, therefore, the image must be three times the size of object, or 3 inches.

Practical Optics

What is the essential difference between crown glass and flint glass?

Crown glass contains lime, while flint glass contains lead. On account of the lead, flint glass possesses greater refractive and dispersive powers. It is denser and heavier than crown glass, but softer.

Crown glass is harder and hence does not scratch so easily, but at the same time is more brittle. Crown glass also has the advantage of lower dispersion. The index of refraction of crown glass is 1.52 and of flint glass 1.62.

Which fuses at the lower temperature, crown glass or flint glass?

Technically speaking, this depends upon the index of refraction. The index of crown glass may be raised as high as the lowest flint, or the index of flint glass may be lowered to the highest crown, when they would fuse at the same time.

But as used in the fused bifocals, the flint fuses very much sooner than the crown; otherwise there could not be such a thing as fused bifocals.

Mention the properties that you consider most essential in glass to be used for making spectacle lenses.

Optical glass must be homogeneous, that is, of the same density and refractive power throughout. It should be perfectly transparent and free from bubbles, striæ and color.

In accordance therewith we have − 1.75 D. sph. ⊃ 4.75 D. cyl. axis 160°.

c + .75 D. sph. ⊃ − 2.50 D. D. cyl. axis 145°.

How may it be determined whether a lens is spheric or cylindric?

Hold the lens at some little distance from the eye and look through it at a straight line on a card, or the edge of a picture frame or window sash. Rotate the lens or give it a circular motion, and if there appears any break in the line a cylinder is shown to be present; the break being caused by the difference in refraction of different parts of the lens. If the lens is a simple sphere no break will be caused in the line by its rotation, because a sphere has the same curvature in all meridians.

Care must be taken to look through the lens at its optical center, otherwise the prismatic effect of the lens will be brought into action, and there will be a break in the line, but in this case the part of the line seen through the lens will be parallel with the line, whereas in the case of a cylinder the line as seen through the lens will be oblique. This illustrates what is known as the "twisting" action of a cylinder.

How can the meridian of least refraction in a sphero-cylinderic lens be located?

In other words, find the location of the axis of the cylinder. Look through the center of the lens at a straight line or edge, rotate the lens and note the position in which the line is continuous, above, below, and through the lens. Make an ink mark on the lens at this position, and then place on a protractor scale and read off the number of degrees.

This indicates the location of one of the principal meridians, but it may be that of least or of greatest refraction, which are always at right angles to each other. The amount of motion in these two meridians will show at once to the experienced eye which one is of least refraction; or if there is any doubt about it, each meridian may be neutralized in turn by a spherical lens.

Express in diopters the power of a lens whose principal focal distance is 150 millimeters.

6.66 D.

Name the various parts of a spectacle frame.

Bridge, eye wires, end pieces, screws and temples.

Has a lenticular lens any advantage other than lightness?

We do not know of any other advantage except lightness and better appearance as in the doing away with the thick edges of strong concave lenses. On the other hand, there may be some disadvantage from the restricted field.

What is meant by a 5° prism?

This means a prism with a refracting angle of 5°.

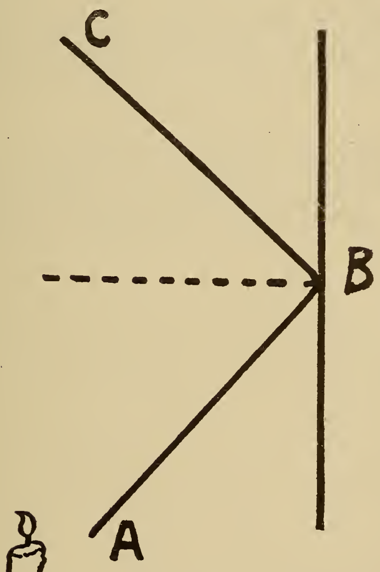


FIG. 18

What is meant by the term "base curve" as applied to toric lenses?

The base curve is the curve of least strength on the toric surface; the three most commonly used are 3 D., 6 D. and 9 D., of which 6 D. is the one usually met with. These are convex in

most cases, although it is sometimes desirable to grind a concave base curve.

How would you determine the optical center of a lens? The axis of a cylinder?

By looking through a lens at a straight line and moving the lens until the line is continuous above, through and below the lens. At every other portion of the lens, except the optical center, the line will appear broken.

By looking through a cylindrical lens at the same straight line and rotating the lens. The portion of the line seen through the lens will be "twisted" or broken by this rotation. Find the portion of the lens where there is no break; this will be one principal meridian, while the one at right angles will be the other. One of these will be the axis which can be determined by motion or by neutralization, the axis being plane and having no power.

What is the focal length of the following lenses placed in apposition: + 4 sph., + 3 sph. ○ − 2 cyl. × 75, + 3.50 sph. ○ + 1 cyl. × 75, − 2 sph., − 4.50 sph., − 1 cyl. × 165?

+ 4. sph.	− 2. cyl. axis	75°	
+ 3. "	+ 1. " "	75°	
+ 3.50 "	− 1. " "	165°	
− 2. "	− 1. S.		
− 4.50 "			
+ 4. sph.			
− 1. "			
+ 3. sph.			

Transpose the following:

To + on − equivalent: + 1.75 sph. ○ + 2.25 cyl. × 85
To + on + equivalent: + 3.50 sph. ○ − 1.25 cyl. × 145
To sphero-cyl. form: + .75 cyl. × 90 ○ − 2.50 cyl. × 180

+ 4. D. sph. ○ − 2.25 D. cyl. axis 175°
+ 2.25 D. sph. ○ + 1.25 D. cyl. axis 55°
+ .75 D. sph. ○ − 3.25 D. cyl. axis 180°

What is the prismatic power of a 5 D. lens decentered 3 mm.?

1 D. lens decentered 10 mm. affords 1° prismatic power, therefore 5 D. decentered 3 mm. develops 1½° prismatic power.

Give the dioptric value of each surface of a wafer of a cement bifocal, the distance correction being − 3 sph. ⊃ + 1.50 cyl. × 90, the addition being + 2.50 D.

+ 3 D. and − .50 D.

In what way does chromatic aberration differ from spherical aberration?

Chromatic aberration depends upon the varying degrees of refrangibility of the different colors of which white light is composed, the violet coming to a sooner and the red to a later focus.

Spherical aberration depends upon the difference in refractive power of the several parts of a lens, the rays passing through the periphery coming to a sooner focus than those passing nearer the center.

A plus lens has a focus of 30 cm.; the index of refraction of the glass used is 1.60; one surface is convex and one a radius of 12 cm.; what is the nature and power of the other surface?

If the radius of curvature is 12 cm. and the index of refraction 1.60, the focal length of such a lens, if plano-convex, is 20 cm., which makes the value of the curvature of this surface 5 D.

But the lens itself having a focus of 30 cm. has only a value of 3.33 D., therefore the other surface of the lens must be concave 1.67 D.

What is the principal focus of a lens?

The place or distance from lens where parallel rays are made to meet after passing through such lens.

How much must a 4 dioptric lens be decentered so that the prismatic action will be 1¼ prism diopters? Figure out the same by means of a formula.

A 1 D. lens decentered 10 mm. develops 1° prismatic power; a 4 D. lens decentered the same distance shows 4° of prismatic value. If 4° prism is developed by 10 mm. decentration, then the desired 1¼° prism will be obtained by $\frac{1\frac{1}{4}}{4}$ of 10; or it may be stated as follows: as 4° is to 10 mm. so is 1¼° to the answer.

In both cases the result is 3.12 mm.

With a compound lens, a plus 2 sphere on a plus 3 cylinder, form an image of a distant arc light. As the card is moved back and forth describe the appearance of the image and the distance at which the most pronounced effects are reached.

This compound lens would show + 2 D. power in one meridian and + 5 D. power in the other; the latter possessing the sharper curve would bring the rays to a focus at 8 inches, and the former at 20 inches.

The bundle of rays on account of being more strongly refracted by one meridian would assume the shape of an oval, the long diameter being at right angles to the stronger curve, until finally they unite in a focal line at 8 inches. Beyond this point there is a place where the rays assume the form of a circle, and they become oval in the same direction as the sharper curve and form a focal line at 20 inches.

What is the dioptric power of a plano-convex lens, the radius of curvature being 25 cm. and the refractive index 1.50?

To find the focal length of a convex lens the rule is to divide the radius of curvature by twice the index of refraction less one.

$$\frac{\text{Rad. or curv.}}{(2\text{ index} - 1)} = \text{focal length.}$$

or substituting the figures

$$\frac{25\text{ cm.}}{2\ (1.50 - 1)} = \frac{25}{1} = 25\text{ cm.}$$

Inasmuch as a plano-convex lens is mentioned and as the focal length of such a lens is equal to twice the length of the

radius, we multiply the above result by two, which gives 50 cm. as the focal length. And as the question asks for dioptric power, we obtain this by dividing 50 cm. into 1 meter or 100 cm., the result being 2 D., which is the answer asked for.

What is the focal length of a 7 D. lens?

In order to find the answer to this question in inches the usual way is to divide 7 into 40, on the basis that 40 inches equal one meter, but as the exact figures are 39.37 inches to the meter, in order to be accurate we should use these figures as follows:

$$7\overline{)39.37}$$
$$5.62 \text{ inches,}$$

which is the answer.

In order to obtain the result in the metric system we divide 7 into 100 cm., as follows:

$$7\overline{)100}$$
$$14.28 \text{ cm.}$$

as the answer.

Which point of the lens surface should be determined before cutting and mounting the lens? How is this point to be located and what is it called?

This has reference to the optical center of the lens, and is located by looking through the lens at a straight line and moving lens until the line as seen through and beyond the lens is continuous and unbroken. This is done for both vertical and horizontal meridians, and the point of intersection is the optical center and is the point where light passes through without refraction at either surface.

It can also be located by looking through the lens at the vertical and horizontal edges of a card and moving lens until these edges are continuous through and beyond the lens, and then the corner of the card will indicate the optical center.

Transpose the following into various possible forms, and state which you prefer, giving reasons for the preference:

+ 4.00 sph. + 1.25 cyl. axis 130°
+ 3.25 sph. – 1.75 cyl. axis 110°
– 2.5 sph. + 3.25 cyl. axis 70°

The *first* may be transposed into anothei sphero-cylinder:

+ 5.25 D. sph. ⊂ – 1.25 D. cyl. axis 40°

or into a cross-cylinder:

+ 4 D. cyl. axis 40° ⊂ + 5.25 D. cyl. axis 130°

Some persons would prefer the original formula, because it is least expensive; while others would give preference to the second formula, because of its periscopic shape.

The *second* may be transposed into another sphero-cylinder:

+ 1.50 D. sph. ⊂ + 1.75 D. cyl. axis 20°

or into a cross-cylinder:

+ 1.50 D. cyl. axis 110° ⊂ + 3.25 D. cyl. axis 20°

In this case the original formula affords a periscopic shape, but the second sphero-cylinder is least expensive.

The *third* may be transposed into another sphero-cylinder:

+ .75 D. sph. ⊂ – 3.25 D. cyl. axis 160°

or into a cross-cylinder:

+ .75 D. cyl. axis 70° ⊂ – 2.50 D. cyl. axis 160°

In this case both of the sphero-cylinders are periscopic, but the second one might be preferred as being somewhat lighter.

Why is it that when an object is viewed through a minus lens and the lens is moved up and down, the object appears to move in the same direction?

At every part of a lens, except exactly at its optical center, there is both refractive and prismatic power, the latter of which causes displacement of objects when viewed through the different portions of the lens. The displacement of an object is always in the direction of the apex of the prism and in a concave lens the apex is at the center; hence, when the center of the lens is moved up, an object viewed through it moves up also; when moved down, object moves down. Therefore, with a concave lens the movement is always in the same direction as the lens.

Describe a toric lens.

A toric lens is one in which one of the surfaces is toroid. A toroid surface is one that shows two curvatures like the bowl of a spoon, the greater curvature being at right angles to the lesser. This affords the effect of a sphero-cylinder all on one surface. The other surface is ground in a deep meniscus form.

What is a meniscus lens?

Meniscus comes from a Greek word, meaning crescent, and is applied to lenses that are ground concave on one surface and convex on the other.

Name several styles of bifocals, with a brief description of the same.

Cemented, bisight, Kryptok and Ultex.

In the cemented form the distance lens is of full size, and the addition necessary for reading is made by means of a thin wafer or segment, which is cemented on by means of Canada balsam to the lower portion of the large lens.

In the bisight and Ultex forms the necessary curves for distance and reading are ground on a single piece of glass.

In the Kryptok form the large lens is made of crown glass and the small lens of flint, and the two fused on account of the difference in their refractive indices; it is a matter of calculation to obtain the desired reading power.

Name the parts of an eyeglass.

Spring, guards, studs and straps.

What is the dioptric power of a lens that focuses parallel rays of light at 10 cm.?

10 D.

How can you ascertain if a lens has been properly centered?

By looking through the lens at a straight line or a cross on

a large card within a few feet, or hanging on the wall across the room. With a convex lens, if weak, these lines may be placed at almost any distance, but if the convex lens is strong the distance must be correspondingly shortened. Another point of importance is that the lens must not be held too close to the eye of the observer—not closer than ten inches, and better if at arm's length.

The position of the lens is then shifted and moved to that place where the lines are continuous vertically and horizontally through and beyond the lens; in other words, where there is no break in the lines. If the point of crossing of the lines agrees with the mechanical or geometrical center, the lens is properly centered; otherwise not. The optical center is indicated by the crossing of the lines, and it can be quickly seen if this is in the proper position or not.

If your trial case contained only spherical lenses, how could you determine the powers of the component elements of a given sphero-cylindric lens?

With a sphero-cylindrical lens there is motion in all directions and I would first notice if the movement is with or against. In this way I would determine if the lens was convex or concave, so as to be able to pick out a neutralizing lens of the opposite kind.

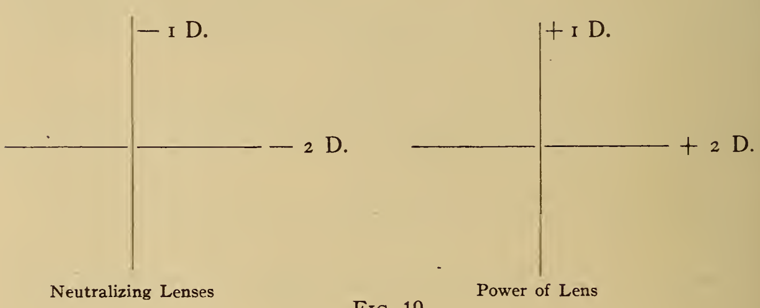


FIG. 19

There is one meridian in which motion is greatest and one meridian in which it is least, and in order to locate these two meridians I would look through the lens at a line or a straight edge and rotate it. There are two positions, and two only,

where the edge is unbroken, and these indicate the location of the meridians of least and greatest curvature.

I would then find a lens that would destroy the motion in the meridian of least curvature and another lens to neutralize the meridian of greatest motion. The weaker lens would be the sphere, and the difference between the two the cylinder with its axis in the direction of the weakest meridian.

Suppose the two principal meridians were vertical and horizontal and a − 1 D. neutralized the former and a − 2 D. the latter.

Then the value of the lens we were neutralizing would be

$$+ 1 \text{ D. sph.} \bigcirc + 1 \text{ D. cyl. axis } 90^\circ$$

What is the characteristic difference between a plane cylindric lens and a sphero-cylindric lens?

In the former one surface is plano and the other ground cylindrical. In the latter both surfaces are curved, one being ground on a spherical-shaped tool and the other on a cylinder-shaped instrument.

In the sphero-cylinder all meridians have power varying in degree; in the plano-cylinder there is one meridian without power—that is, in the direction of its axis.

How are lenses for optometric practice usually numbered?

There are two systems by which lenses are numbered—the older, or inch system, which shows the focal distance of the lens, and the newer and better system, the dioptric or metric, which expresses the refractive power of the lens.

Explain the dioptric system of numbering and measuring lenses.

The standard of measurement, or the unit of the dioptric system, is a lens of 1 D., which has a focal distance of one meter. This lens is comparatively weak and the stronger lenses in common use are multiples of this unit. Weaker lenses than the unit are expressed in decimal fraction, one-quarter, one-half and three-quarters of a diopter being written .25 D., .50 D., and .75 D.

The power of any lens expressed in diopters is the reciprocal of its principal focus expressed in meters; as, for instance, a 2 D. lens has a focal distance of half a meter, a lens of 4 D. of one-quarter meter.

The two chief objects urged against the inch system—the difficulty of combining vulgar fractions and the irregular intervals between the lenses—are entirely removed in the dioptric system, where the decimal fractions can be as easily added and subtracted as whole numbers and where there is a regular graduation of increase of .25 D.

What prismatic power would be produced by decentering a 4 D. spherical lens 5 mm.?

The rule of decentration is as follows: For every decentration of 10 mm. there will be as many degrees of prismatic power as there are diopters of refractive power.

Therefore, a 4 D. lens decentered 10 mm. would develop a prismatic value of 4°; but as the question names a decentration of 5 mm. the prismatic power would be one-half of the amount named, or 2°.

Name, with respect to their curvatures, the different kinds of lens surfaces used in optometric practice.

The surfaces may be enumerated as convex, concave, spherical, cylindrical and toric.

Prisms are sometimes used in optometric practice, but the surfaces of prisms (if uncombined with other lenses) are plane, not curved.

How is it possible to tell the principal focus of a concave lens without the use of neutralizing or other lenses, and without the use of a lens measure?

The lens is to be held in such a position in front of a screen that the rays from a distant source of light as, for instance, the sun, will pass through it and fall upon the screen. A central dark spot will be seen upon the screen with an area of brightness surrounding it.

The lens is then moved to and from the screen until a point is found where the area of brightness is twice the diameter of

the concave lens, and then measure the distance of the lens from the screen, which will be the principal focal distance of the lens.

How would you be able to tell whether a prescription for a prism has been filled with the amount of prism ordered; no more, no less?

In the first place, we could tell by neutralizing the prism with one from the trial case, placing base over apex. For instance, if we found that the line was broken and that the part seen through the lens was deflected to right, we would know a prism was present and that its base was to the left. We take a prism from the test case, placing it base to the right and changing the prism until we found one that restored the break in the line and made it continuous, above, below and through the lens.

Or we can make use of our knowledge of the fact that rays are deflected in the proportion of 1 cm. for each meter of distance. For this purpose we have a card showing a series of parallel lines which are numbered and separated by an interval of 1 cm.

Then we hold the prismatic lens over these lines and note the amount of displacement and this will show the strength of the prism.

Suppose we have a series of vertical lines numbered from left to right, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, and equidistant from each other. The end or O line on the right is made longer than the others and at its foot is placed an ×. The prismatic lens is held with its base to the right, and the × on the O line is viewed through it, when it will be seen that the × has been displaced to the left and coincides with the line marked 3, which represents the strength of the prism.

If the prism is held at a distance of 1 meter the lines should be 1 cm. apart; if a distance of half a meter, then ½ of a cm. apart, and this ratio must be always maintained or the accuracy of the measurement is destroyed.

Transpose the following toric lens: Minus surface 5 D., plus surface 6 and + 7.50.

+ 1 D. sph. ⊃ + 1.50 D. cyl.

A lens measure made to measure lenses made of glass with a refractive index of 1.52 shows one side of a lens to be — 1.25 and the other to be + 2.75, but the glass of which this particular lens is made has an index of refraction of 1.62; what will be the radius of curvature of a plano-convex lens, with an index of refraction of 1.52, which will have the same effect on light as the first-mentioned lens?

The lens measure shows this lens to be a periscopic convex lens of 1.50 D. when used on glass with an index of refraction of 1.62, but as this lens measure was made to measure glass with a refractive index of 1.52, there would be a corresponding increase in the refractive power of the lens, as shown by the following proportion:

$$.52 : .62 :: 1.50 : X$$

in which case X = 1.78 D., which represents the real value of the lens.

Now, then, the question to be solved is, what is the radius of curvature of a lens of this power with an index of refraction of 1.52? In order to obtain this we multiply focal distance by the index of refraction, less unity. The focal distance of a + 1.78 D. lens is approximately 22 inches. The problem is 22 x .52 = 11.44 inches, which is the radius of curvature of the lens.

How is it possible to measure approximately the strength of a biconcave lens without either neutralizing lenses or a lens measure?

By using the surfaces of the lens as concave mirrors and then make calculations on the principle that the focal length of a concave mirror is equal approximately to one-half the radius of curvature.

For instance, if each surface of the lens focuses light by reflection at a distance of two inches, then the radius of curvature of each surface would be 4 inches, equivalent to a 10 D. value.

If the index of refraction of the glass is 1.50 then the problem is:

$$(-\ 1.50 - 1)\ \ (-\ 10\text{ D.} + -\ 10\text{ D.})$$

or

$$.50 \times -\ 20\text{ D.} = 10\text{ D.}$$

which would be the approximate measure of strength of such biconcave lens.

In looking through a lens at a small distant object, and moving the lens from side to side, the distant object seems to have movement; what is the reason for this?

At the optical center of a lens the two surfaces are parallel for a very minute point, and as a result the axial ray passes unrefracted. As the optical center is departed from the surfaces show a curve which results in the development of refractive and prismatic power, increasingly so from center to periphery.

As the lens is moved from side to side before an eye which is fixed on some distant object, the visual line passes through different parts of the lens, each in succession showing prismatic power in the same direction. Now the effect of a prism is to cause displacement of an object looked at, and it is impossible to view an object through a prism without such displacement becoming noticeable.

The displacement is always in the direction of the apex of the prism and hence in a convex lens, where the apex is at the periphery, the motion is opposite; while with a concave lens, where the apex is at the center, the motion is with.

Under what circumstances will two strong lenses, one minus and the other plus, each of the same curvatures, neutralize each other?

With strong lenses it is almost impossible to get perfect neutralization, but the thinner the lenses the more we can approximate neutralization. Also if the lenses to be neutralized are plano-spheres, so that the two plane surfaces can be placed in apposition. There is difficulty in finding neutralization all over the lens, especially in the peripheral portions, on account of spherical aberration. But as the center of the lens is the portion patient looks through, this is the part of the lens to which most attention is given in neutralizing.

Explain the effect of spherical and chromatic aberration in lenses for spectacles and eyeglasses.

In the weaker numbers of glasses that are used for spectacles, aberration is so slight that it can practically be ignored. In the stronger numbers used in telescopes and microscopes, aberration must be and is corrected.

The effect of spherical aberration is to cause the wandering of rays from a single focus and thus make it more or less diffuse, while the effect of chromatic aberration is to cause an unequal refraction of colors and thus give the focus a fringe of rainbow colors.

Name some important points in a spectacle lens.

It should be perfectly clear and transparent, absolutely without specks, flaws or bubbles, and surfaces well polished. It should be of the proper size to correspond to the pupillary distance, correctly centered to meet the visual axes and light in weight.

In how many different ways can a sphero-cylinder be made up?

There are always two ways in which a sphero-cylinder can be made up, one in which the cylinder is convex and the other in which it is concave, the axis of cylinder in the two ways being at right angles to each other. The prescription can also be made up in the form of a toric to give the same effect; although then it is not, strictly speaking, a sphero-cylinder.

Why is the image of a point formed by a cylinder a line and not a point?

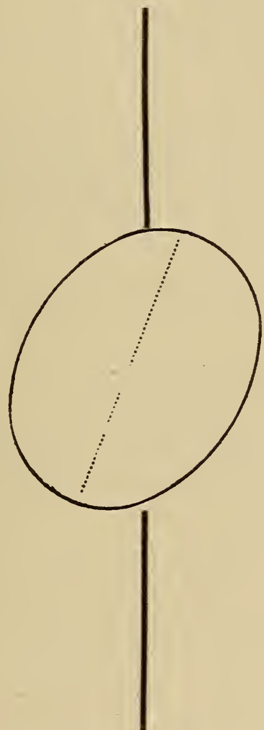
The bundle of rays as they strike the lens may be represented by a circle. If the lens be a sphere with equal power in all meridians, the circle will be focused to a point.

If the lens be a cylinder with no power in the meridian of its axis, the light will be subject to the action of the meridian at right angles, and as the rays are converged by this one meridian only they are brought to a focal line in the same meridian as the axis.

If a compound lens, minus on minus, were placed before you with the axis of the cylinder set with an inclination somewhere between 90° and 180°, state how you would determine by simply looking through the lens at the crossbars of a window frame, that

the axis was not between zero and 90°. Illustrate your answer with a diagram.

If a straight line be looked at through a cylindrical lens, either simple or compound, the line will appear straight in only two positions of the lens, the meridian of its axis and the meridian at right angles to its axis. In all other positions the line will be inclined to one side or the other. Hence, in looking at the



Showing Displacement of a Straight Line by Rotation of a Cylinder

Fig. 20

crossbars of the window, they would appear broken if the axis of the cylinder was oblique, whereas if the axis was at 90° or 180° the crossbars would be continuous beyond and through the lens.

Transpose the following into a resultant prism, and indicate the angle of inclination of the base-apex line in standard notation or by diagrams: R. E. 2¼° prism base in; 1° prism base up.

We make a diagram drawing straight lines proportional in length to the deviating powers of the prisms, arranged according to the directions in which the apices of the prisms point.

In this case we have a prism 2¼° base in, which is represented by a horizontal line 2¼ cm. long as the deviating power

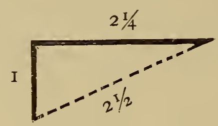


Fig. 21.

of the prism towards the right. From the base of this prism we draw a vertical line 1 cm. long to represent the deviating power of the prism downward. The strength of the resultant prism is 2½° as indicated by the length of the dotted line, which is 2½ cm., and the inclination of its base-apex line can be found by comparing with a protractor.

What advantage has a periscopic lens over a double convex or concave lens mounted in spectacles?

The usual form of periscopic lens is ground with what might be called a base curve of 1.25 D. In periscopic convex lenses the concave curve is 1.25 D. In periscopic concave lenses the convex curve is 1.25 D.

The special advantages claimed for periscopic lenses are that they conform to the front convex surface of the eye, allowing the lenses to be brought closer to the eye and still leave room for the play of the lashes, and also to prevent, as far as possible, the cylindrical effect that is developed when the visual line passes obliquely through the lens.

But it has long since been recognized that the usual periscopic lenses presented these advantages but imperfectly, and this led to the manufacture of the deep meniscus or toric lenses, with a concave curve of 6 D. or more, which are fulfilling the requirements for periscopic lenses and are growing rapidly in popular favor, notwithstanding their greater expense.

Which surface of a + 3 D. sph. ⊂⊃ + 1 D. cyl. should be placed nearer the eye?

The rule is to place the greatest concave or the least convex surface next to the eye and in accordance therewith the + 1 D. cylindrical surface should face inwards.

Perhaps it would be better to transpose this lens into a + 4 D. sphere ⊃ − D. cyl. and place the concave cylindrical surface next to the eye.

What is the effect in strong plus lenses of having them set nearer to the eyes in the frames than they were in the test with the trial case lenses?

A convex lens when set closer to the eyes loses in effective power. In the ordinary lenses the change is scarcely enough to be considered, but in strong lenses it might be well to take it into account.

What difference should there be in the position of distance and reading glasses?

The optical centers of reading glasses should be a little closer and a little lower than for distance. The plane of the glasses should be vertical in distance glasses, while for reading they should be angled slightly forward, so that in each case the visual line may be at right angles to the plane of the lenses.

How is a riding frame manipulated if one ear is higher than the other?

The temple on this side should be bent upwards close to joint, which will result in lowering this lens and make them both of the same height.

Can a prismatic effect be produced by glasses that are properly centered?

If the glasses were properly centered for distance there would be some prismatic effect at the reading point; and if properly centered for reading there would be some prismatic effect at distance. In other words, there is bound to be some

prismatic effect when glasses are used at a distance different from that for which they are centered.

What measurements must be taken in fitting spectacles to face?

Pupillary distance, height of bridge, width of base and inclination of bridge. To these may be added temple width and temple length.

In a case where a strong concave lens is required (say 14 D.), but the nose is sensitive to the weight of the glasses, what form of lenses can be supplied which will reduce the weight to the minimum?

Flattened face lenses in which the thick peripheral edge is ground down; or lenticular, in which a small scale is cemented on a larger lens.

A prescription reads + 1.50 for distance and + 4 D. for near. The distance glass is supplied in the standard periscopic form. What will be the power of each side of the wafer as shown by the lens measure?

In a periscopic convex lens the standard concave surface is 1.25, on which the wafer is cemented. Hence its one surface must be + 1.25 to correspond to the surface to which it is cemented, and its other surface + 1.25 to make up the 2.50 D. that is to be added to the distance glass.

In using a lens measure we cannot place its points against the cemented surface of the wafer, but we can place them against the surface of the distance lens, and we know they must both be of same value but of opposite curves. If the wafer is large enough we can place the points of the lens measure against its other surface, and thus we are able to ascertain the curvature of both surfaces of the wafer.

Given a plus compound, explain three ways in which the two meridians can be located and the power of the compound measured or calculated.

The easiest way would be by the lens measure. The most accurate way, but involving a little more trouble, would be by neutralization by a similar minus compound.

Also by looking through the lens at a line or a cross and locating the principal meridians, and then neutralizing each in

turn by a minus sphere. Obtaining thus the power of each meridian, transposition is made to a sphero-cylinder.

How can a toric lens be made and yet not be periscopic?

Notwithstanding a popular notion to that effect, a toric lens does not necessarily mean a periscopic shaped lens. The word toric implies that two curvatures are ground on one surface, as instanced in the under surface of the bowl of a spoon. The other surface of the lens may be flat or convex, according to the fancy of the prescriber, but, as a matter of fact, it has been found convenient to grind one surface deeply concave, but this is not essential to a toric lens. Of course, it is understood that if one surface is made concave the convexity of the other surface must be correspondingly increased.

If it was desired to grind + 1 D. sph. ◯ + .50 D. cyl. axis 90° in a toric form we could have the toric surface + .50 D. in one meridian and + 1 D. in the other meridian, and the second surface + .50 D. in all meridians. This would constitute a toric lens, but it would not be periscopic.

What is an achromatic lens and on what principle is it made?

The dispersive power of lenses is not always in proportion to their refractive power. The refraction of crown glass is in relation to its dispersion as 152 is to 203, while of flint glass the ratio is 162 to 433. This shows the high dispersive power of flint glass.

These facts are made use of in the manufacture of achromatic lenses, which are a combination of these two different kinds of glass, so proportioned that the dispersion of the convex lens shall be neutralized by the concave lens, but not all of its refractive power, with the result of making a refractive lens, robbed of its dispersive power, able to make an image without colored edges. In such a combination the convex lens is of crown glass and the concave lens of flint glass.

What is the advantage of the meniscus form of lenses?

With flat lenses, as the eyes turn up and down, in and out, the line of vision passes obliquely through the lenses, causing an added cylindrical effect. This is to a great extent obviated by

the meniscus-shape lenses, whose concave surface corresponds to some extent to the convex surface of the eye, thus affording better vision as the eyes turn in different directions. Also they can be brought closer to the eyes and thus shut out many reflections.

What is the rule for the decentering of lenses? If a 5 D. sphere is decentered 3 mm., what will be the prismatic effect?

For every decentration of 10 mm. there are as many degrees of prismatic power as there are diopters of refractive power. A 5 D. lens decentered 10 mm. would show 5 prism diopters, and decentered 3 mm. would be 3/10 of 5 = 1½ prism diopters.

The finding of a certain case is O. U. + 50 sphere, combined with + 75 D. cylinder axis 90°. These are ordered in torics on a + 6 base curve. What will the lens measure show on the two surfaces of the lens when completed and in the mountings?

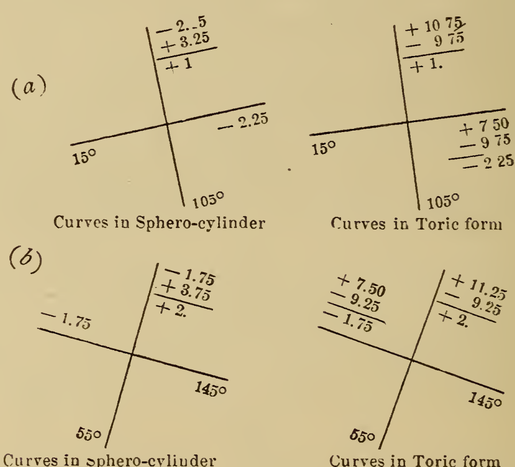


FIG. 22.

If + 6 D. is to be the base curve it is the lowest curve on the toric surface, which would be the vertical meridian, and + 6.75 in the horizontal meridian. Then, in order to afford the desired power in both meridians, a — 5.50 D. curve is ground on the inner surface.

The following pair of lenses are ground on a + 7.50 D. base curve:

(*a*) *R. E., – 2.25 D. S. = + 3.25 D. C. axis 15°;*
(*b*) *L. E., – 1.75 D. S. = + 3.75 D. C. axis 145°.*

Give all the curves of the lenses in their principal meridians, indicating them on crosses.

Write an order for riding bow frames, giving all the dimensions for a patient with a narrow pupillary distance and a broad nose.

Pupillary distance, 2 3/16 inches; height bridge, 1/16 inch; inclination of bridge, 1/16 inch; in width base of bridge, 13/16; 0 eye.

If you should order a + 1 D. sphere combined with a – 1.50 cylinder axis 90° in the form of a toric lens, what would you find on checking up the glasses with a lens measure?

Unless otherwise ordered, the toric curves are usually on the convex surface and the base curve is + 6 D.

On the outer surface there would be + 6 D. curve in the horizontal meridian and + 7.50 D. curve in the vertical meridian. On the inner surface there would be – 6.50 D. in all meridians.

If you should order a + 1 D. sphere combined with a – 1.50 cylinder axis 90°, the same to be made in the toric form and on a base curve of – 6 D., what would you find with the lens measure?

On the inner surface there would be a – 6 D. curve vertically and a – 7.50 D. horizontally. On the outer surface there would be + 7 D. in all meridians.

How is the optical center of a lens found?

By holding the lens some little distance from the eye and looking through it at a straight line and moving the lens until the line is continuous above, through and below the lens. This is repeated with the lens turned quarter way around, and the point of intersection of the two lines will indicate the location of the optical center. Or a cross may be used and the lens moved

until the arms are continuous without and within the lens, and the intersection of the arms of the cross will indicate the optical center.

State the powers as shown by a lens measure in the case of a toric lens + 8 D. sph. ⊂⊃ + 2 cyl. axis 90°, the toric being made with a base curve of + 6. Will such a lens be a meniscus?

On the outer surface there will be + 6 D. power in the vertical meridian and + 8 D. power in the horizontal meridian. On the inner surface there will be a + 2 D. power in all meridians. This is not a meniscus lens.

What is the advantage of the metric system of numbering lenses?

It does away with all the disadvantages of the inch system. The unit being comparatively weak the stronger numbers are multiples of the unit and can be expressed in whole numbers. There are no vulgar fractions to be added or subtracted, but instead there are decimals which are easy of manipulation. The interval between the lenses is regular, it expresses the dioptric power of the lens instead of its focal distance, and it is a uniform system all over the world.

State the powers as shown by a lens measure in the case of a toric lens + 8 D. sph. ⊂⊃ + 2 cyl. axis 90°, the toric lens being made on a base curve of — 6 D. Will such a lens be a meniscus?

On the inner or toric surface — 6 D. power in horizontal meridian and — 8 D. power in vertical meridian.

On the outer surface + 16 D. power in all meridians.

This lens will be a meniscus.

How many refracting surfaces has a Kryptok lens in its reading portion? How many refracting surfaces to the distance part of the lens?

In the reading portion there are three refracting surfaces, the two outer surfaces, which are in contact with the air, and the inner surface, where the flint fits into the crown glass.

The distance portion has the usual two refracting surfaces both in contact with air.

On what principle is based the test for finding the optical center of a lens?

At the small portion of the lens occupied by the optical center the surfaces are assumed to be parallel and there is no bending of rays of light. But as this point is departed from, curvature comes into evidence with refractive and prismatic power, increasing from the center to the periphery.

Taking a + 1.50 D. lens from the trial case, what other lens must be added to it to produce a positive focus of two meters?

A focal distance of two meters, or eighty inches, is produced by a + .50 D. lens; hence in order to reduce this + 1.50 D. lens to such power we must add − 1 D.

What is the dioptric power of a lens which, being decentered 5 mm., shows a prismatic deviation of two prism diopters?

The rule is that for every decentration of 10 mm. there are as many diopters of prismatic power as there are of refractive power. As this question calls for a decentration of 5 mm., there would be half as many prism diopters as there are refractive diopters. And as the deviating power of a prism is equal to only one-half of its refracting angle, there would be only one-fourth as much prismatic deviation as there are diopters of refractive power.

Therefore, in order to produce a deviation of 2 prism diopters, the power of the lens must be 8 D., which, decentered 5 mm., would show 4 diopters of prismatic power and 2 diopters of deviation.

On what particular quality of the glasses used does the optician depend to secure the necessary reading addition in fused bifocals?

On the fact that the index of refraction of the reading addition is so much higher than that of the distance glass, that

with the same curvature on each the former would show a much greater refractive power, and when properly figured out would afford the additional power desired for reading.

What curvature must be given to the two surfaces of a wafer to produce a 2.50 D. reading addition, the distance correction being + 1 D. cylinder, the lenses to be made toric on a + 6 D. base?

As the lens is a plane cylinder and the base curve of the toric surface is to be + 6 D., the inner surface must be ground − 6 D. in order to produce neutralization in the meridian of the axis of the cylinder. Therefore, the one surface of the wafer must be + 6 D. in order to fit close to the − 6 D. surface, and then in order to reduce the power of the wafer to + 2.50 D. its other surface must be − 3.50 D.

Why should the optic centers of a pair of lenses for close work be 2 to 3 mm. nearer together than the optic centers of lenses for distant vision?

On account of the greater convergence of the visual lines in near vision, and in order to avoid prismatic effect.

What particular advantage has the meniscus form of lens for bifocal glasses?

In order to prevent the visual lines passing obliquely through the lenses, as will necessarily be the case with flat lenses, as the eyes turn down in near vision, whereas with the meniscus form of lenses the visual lines are more nearly at right angles to the plane of the glasses, which is the condition to be desired in order to avoid any extra cylindrical effect.

How can you find the principal focal length in inches and in millimeters of a + 6 D. lens?

In order to find the principal focal length in inches, we divide the 6 D. into 40 inches, and the result is approximately 6½ inches.

In order to find it in millimeters, we divide the 6 D. into 1,000 millimeters, and the result is approximately 166 mm.

What is the power of each surface of a scale used in a cement bifocal, where the prescription is − 1 D. sph. = + 1.25 D. cyl. axis 180°, and + 1.75 for reading?

The scale would be cemented on the concave surface of this sphero-cylinder, which, being − 1 D., would call for + 1 D. on one surface of the scale, and the other surface + .75 D., to make up the desired power.

Why is it necessary to locate the optical center of a lens before edge grinding and mounting?

In order to prevent any prismatic effect in the completed lens.

In what two ways is the strength and character of a lens found?

By the lens measure, which is the easiest and quickest way, and by neutralization, which, while more troublesome, is more accurate.

How may the axis of a cylindrical lens be found?

By the lens measure, or by finding that meridian of a lens in which there is no motion.

Look through the lens at a straight line and rotate the lens until the line as seen through and beyond the lens forms one unbroken line; this will be one of the principal meridians, either that of greatest refraction or of no refraction at all. The latter, being the axis, could be determined by the absence of motion.

Suppose we wish a toric lens to have a total dioptric power equal to + 1 $\bigcirc$ + .50 cyl. axis 120°, and the lens measure to show the power of one surface to be − 6 D., what will be the powers of the two principal meridians of the toric surface?

This can be easily worked out diagrammatically. The first diagram shows the power of each of the meridians of the sphero-

cylinder, and the second diagram the complete toric lens, from which it is learned that the powers of the two principal meridians on the toric surface are + 7 in the 120th meridian and + 7.50 in the 30th meridian.

A toric lens, which is built up from a base curve of 6 D. on the toric surface. The outside surface of such lens would show a + 6 D. curve in the 90th meridian and a + 7 D. curve in the 180th meridian, while the deep concave surface towards the eye would be − 6 D.

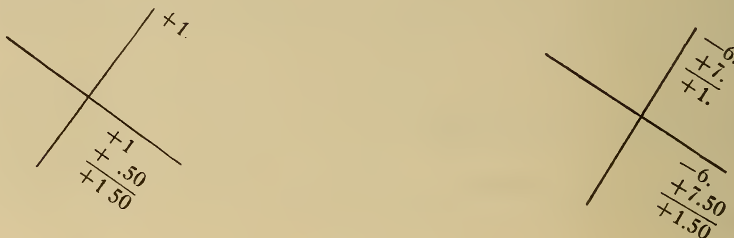


Fig. 23

To what crossed cylinder from the trial case does the following correspond: 30th meridian + 3.25 D., and 120th meridian + 4.25 D.?

Inasmuch as axis is always at right angles to meridian, we have + 3.25 D. cyl. axis 120° ⊃ + 4.25 D. cyl. axis 30°.

In what way does crown glass differ from flint glass as to dispersion and refractive index?

Crown glass has a lower index of refraction and shows less dispersion, while flint glass has a higher index of refraction and a much greater power of dispersion.

This difference in dispersive power is made use of in the manufacture of achromatic lenses, where the convex lens is made of crown glass and shows an excess of refractive over dispersive power, and the concave lens is made of flint glass and shows an excess of dispersive over refractive power. This relation is such that the concave lens corrects the dispersion of the convex lens without neutralizing all of its refraction, and the combination will be an achromatic lens, which is refractive but not dispersive.

In prescribing a high power concave lens, how can the weight of glass be reduced without decreasing the size of lens?

By grinding down or thinning the marginal parts of the lens, sometimes called "flattened face," and known to the trade as lenticular lenses.

How can the axis of the cylinder in a compound be located when the sphere is high and the cylinder is of low power?

By looking through a pinhole the preponderance of the sphere is very much reduced and then the presence of the cylinder soon becomes evident. This is a little practical point that is not as generally known as it should be.

What is decentered lens and how can it be decentered?

A decentered lens is one in which the optical center has been moved away from the geometrical center, by cutting the lens out of the blank to one side. The amount of decentering depends upon the size of the blank, and as these are not very large the limit of decentration is about 3 mm.

How is the optical center of a lens found?

Hold the lens some little distance from the eye and look through it at a straight line, moving the lens until the line is continuous above, below and through the lens, and mark the same with ink. Turn the lens around and repeat the same procedure with the meridian at right angles to the first. The intersection of the two lines will indicate the optical center of the lens.

What is the difference in the nature of the surface of a sphero-cylinder and a toric lens of the same dioptric power?

In a sphero-cylinder one surface is ground with a spherical curve and the other surface with a cylindrical curve. In a toric lens there are two curvatures on one surface, thus giving the effect of a sphero-cylinder all on one surface.

What is an achromatic lens, and does it correct all chromatic aberration?

An achromatic lens is a compound lens made up of a convex lens of crown glass with an excess of refractive over dispersive power, and a concave lens of flint glass with an excess of dispersive over refractive power. In this way the dispersion is overcome without neutralizing the refraction, and the combination will be a refractive but not a dispersive lens, producing a white spot free from colored edges. We assume it corrects the chromatic aberration and so it does for all practical purposes, but as all instruments have their limitations, it may fail to do so perfectly.

What is the purpose of bifocal lenses, and why are they sometimes not satisfactory?

To hold before the eyes for immediate use the two pairs of glasses that are necessary for distant and near vision in a presbyopic ametrope.

The chief reason why they are not satisfactory is that in looking down as in walking or stepping, the person looks through the lower part of the lenses which are fitted for reading at 12 to 15 inches, whereas the ground or steps are at a distance of 65 to 70 inches.

What are some of the advantages and disadvantages of the use of Canada balsam in bifocals?

The advantage is that it is easy to use, while the disadvantages are that it does not become perfectly hard, and hence when glasses are heated or vigorously rubbed the wafers are apt to slip.

A segment for reading is attached to a distance lens whose power on the surface to which the segment is attached is minus 1.25. The power to be added for reading is plus 1.50; what will be the power of each of the surfaces of the segment?

This is simply the attachment of a segment to the usual form of periscopic convex lens, which always shows on its inner surface a curvature of − 1.25 D. As this is the surface to which the segment should be attached, the latter must have a corresponding

convex curve, which would be + 1.25 D. on one surface. To get the total power of + 1.50 D. which it is desired to add for reading, the extra power needed over the + 1.25 D. will be + .25 D., which will be the power of the other surface. Hence the segment will be + 1.25 D. on one surface and + .25 D. on the other.

What effect is produced by the decentration of a lens?

A prismatic effect, the amount of which depends upon the extent of the decentration, and the curvature of the lens, in the proportion of 1° of prismatic power for every diopter of refraction power, when decentered 10 mm.

What constitutes the axis of a cylindrical lens, and how is it found and numbered?

That meridian of the lens which is plano or without curvature constitutes the axis of the cylinder. In a plano-cylindrical lens it coincides with that meridian in which there is no motion. Or it may be found by looking through the lens at a straight line and rotating it to that position where the line is continuous and unbroken, and which will indicate the position of one of the principal meridians, the other principal meridian will be exactly at right angles, one of which will be the axis as indicated by the absence of motion.

How should glasses be adjusted so as to serve for both distance and reading?

It is impossible to adjust glasses so that they will be accurately centered both for distance and reading, as the centers of reading glasses should be closer and lower than those for distance. The only thing that can be done is to strike a compromise, and when the same glasses are used for both purposes to make the centers slightly lower and slightly closer than would be proper for distance, but not so low or so close as would be desirable for reading alone.

Write a prescription that shall contain a cylindric element for both eyes, with a difference in the spheric element of at least

2 D. and with a presbyopic addition of 1.75 for each eye. The lenses are to be made in cemented bifocal form. State what decentration is necessary in order that there shall be no resulting imbalance when the wearer is looking through the reading portion of the lens.

We will write supposed prescription as follows:

$$\frac{\text{R.} + 1.50 \text{ D. S.} \bigcirc + .50 \text{ D. cyl. axis } 90^\circ}{+ 1.75 \text{ D. added}}$$

$$\frac{\text{L.} + 3.50 \text{ D. S.} \bigcirc + .50 \text{ D. cyl. axis } 90^\circ}{+ 1.75 \text{ added}}$$

As the pupillary distance for reading is 4 mm. less than for distance, there is produced in reading vision a decentration of 2 mm. outward for each eye, which for the 2 D. value in the distance lens of right eye is equivalent to .4°.

For the left eye under the same conditions the 4 D. of refractive power would afford a prismatic power of .8°.

The segment must be decentered inwards in order to neutralize the prismatic effect of the distance lens. If a + 1.75 D. lens decentered 10 mm. produces 1.75° prismatic power, in order to get .4° the problem would be

$$1.75 : 10 : : .4 : X$$

$$X = \frac{4.}{1.75} = 2.29 \text{ mm.}$$

And as the segment must be decentered inwards 2 mm. anyhow, the total decentration of segment for right eye would be 4.29 mm.

As the distance lens for left eye is twice as strong, the amount of decentering of segment to overcome it would be 4.58 mm., which added to the customary decentering of 2 mm., would make a total decentering of left segment 6.58 mm.

Which side of a toric lens is the base curve, the inner or outer?

The base curve is the least curve on the toric surface, and as this is usually on the convex surface the base curve is mostly out. But the base curve may be on the concave surface and then it is in.

If a spherical lens has a deep concave curvature on one side, is it a toric sphere or a meniscus?

The word toric implies two curvatures on the same surface, and therefore strictly speaking a sphere cannot be a toric. But, on account of the deep concave curve that is usually ground on toric lenses, the term has come to be applied to all lenses showing such a curve even though they be spheres; therefore, a toric sphere and a meniscus are practically the same thing.

Explain the construction of the spherometer and state its limitations.

The spherometer, or lens measure, has three projecting metal pins, the two outside ones fixed and the central one projecting beyond the other two, movable and connected with a spring, which controls the pointer on the dial which indicates the dioptric number of the lens. When used on a lens the central pin is depressed and causes the pointer to revolve and indicate the power of the lens.

The limitations of the instrument are that it measures only the curvature of the surface, and takes no account of the index of refraction of the glass of which the lens is made. If all glass was made of the same index of refraction the lens measure would always be correct. But, inasmuch as the index varies, it would be correct for only one particular index, and incorrect for lenses of other indices.

If a hypermetrope is wearing a pair of + 4 D. sph., and these are by mistake decentered outward 6 mm. each, what is the amount of prismatic effect produced, and which direction are the bases?

On the basis of 1° for each dioptric when decentered 10 mm., the effect in this case would be 2.4° for each eye bases outwards.

The lens measure shows the inner surface of a toric lens to be − 4 D. sphere and the outer surface a + 6 D. in the 90th meridian, + 8.25 D. in the 180th meridian; what is the power of the lens, and what is its base curve?

The base curve would be + 6 D. and the value of the lens + 2 D. S. ⊃ + 2.25 D. cyl. axis 90°.

What lens can be combined with a + 2 D. S. ⊃ + 1 D. cyl. axis 90° that will decrease the cylinder and increase the sphere?

If a cylinder is placed at right angles then the power of both sphere and cylinder is changed; if the added cylinder be concave the sphere is decreased and the cylinder increased. If the added cylinder be convex the sphere is increased and the cylinder decreased.

Suppose, for example, we add + .25 D. cyl. axis 180° to the given formula, then we have + 2 D. S. ⊃ + 1 D. cyl. axis 90° ⊃ + .25 D. cyl. axis 180°.

By the rules of transposition this is equivalent to + 2.25 D. S. ⊃ + .75 D. cyl. axis 90°.

What lens can be combined with the above that will increase the cylinder and decrease the sphere?

A concave cylinder with axis at right angles. Suppose we add − .25 D. cyl. axis 180° to the given formula, as follows: + 2 D. S. ⊃ + 1 D. cyl. axis 90° ⊃ − .25 D. cyl. axis 180°.

Transposing this cross cylinder and adding the sphere, we have + 1.75 D. S. ⊃ + 1.25 D. cyl. axis 90°.

If you had a case calling for + 1.25 D. S. ⊃ + 0.75 D. cyl. axis 90°, and the lenses were to be torics with minus 6 D. curve next to the eye, what would be the curves on the outside of the lens?

The best way is to make a cross showing the value in each meridian, to which the toric transposition must be made to conform.

Vertical meridian: + 1.25	Horizontal meridian: + 1.25 + .75 + 2.00

Sphero-cylindrical Values

Vertical meridian: − 6. + 7.25 + 1.25	Horizontal meridian: − 6. + 8. + 2.

Toric Curves and Values

In order to maintain the powers of the sphero-cylinder, the curvatures of the outer surface would be + 7.25 vertically and + 8 horizontally.

This would mean a base curve of + 7.25, but as a matter of fact the base curve is usually 6 D. on the toric surface, instead of 6 D. on the spherical surface.

A sphero-cylindrical lens has its axis set at some unknown angle; how would you ascertain at what angle the meridian of greatest refraction is placed? At what angle is the meridian of least refraction? Are these two angles always to be found at right angles to one another? If they are, explain why; and if not, why not?

In a sphero-cylindrical lens there are two chief meridians to be considered; one of least refraction and one of greatest refraction. In order to ascertain the location of these meridians, a straight vertical line should be looked at through the lens; the edge of a window sash or a picture frame will answer. The lens should be held some distance from the eye and as it is rotated the part of the line that is seen through the lens will break away from that part of the line seen above and below the lens, and then come back to its original position.

The lens is rotated to that point where the line is continuous above, below and through the lens, and this will represent one of the chief meridians of the lens, and the other meridian will be exactly at right angles to it. The lens is then moved along these two meridians, when the meridian of greatest refraction is that in which the movement is the most decided, and the meridian of least refraction that in which the movement is least noticeable.

The meridians of least and greatest refraction are necessarily at right angles to each other on account of the nature of the curves, the former corresponding to the axis of the cylinder where the power is that of the sphere alone, and the latter at right angles to the axis where the power is equal to that of the sphere and cylinder combined.

Describe very carefully what will be seen on looking at a horizontal window bar against the bright sky through a thin prism held with its base upwards.

That part of the bar seen through the prism will be displaced downwards or in the direction of the apex of the prism.

Prisms cause dispersion of light, but this will scarcely be noticeable in an experiment like this.

A person, aged sixty, brings you the following prescription for distant vision:

R. E. – 2 D. sphere ⊃ + 1.50 D. cyl. axis 90°
L. E. – 1 D. sphere ⊃ + .75 D. cyl. axis 90°

Can you improve on this prescription without altering the power? What glasses would you give him for reading at 14"?

This prescription can be transposed into

R. E. – .50 D. S. ⊃ – 1.50 D. cyl. axis 180°
L. E. – .25 D. S. ⊃ – .75 D. cyl. axis 180°

But this transposition does not present any advantages over the original because although they might be lighter, the periscopic effect would be lost. For this reason we would choose the former, and also because of the vertical position of the axis of the cylinders, which is preferable.

At the age of 60 the amplitude of accommodation of the average eye is about 1 D., of which the person can use one-half for near work. In order to read at 14 inches without accommodation, a lens of + 2.75 is called for, but as this patient can supply .50 D. of accommodation, the presbyopic addition would be theoretically + 2.25, but as a matter of fact and judging from experience we would say that it ought to be at least + 2.50 D.

If we add these to the first formula we have

R. E. + .50 D. S. ⊃ + 1.50 D. cyl. axis 90°
L. E. + 1.50 D. S. ⊃ + .75 D. cyl. axis 90°

If we add to the second formula we have

R. E. + 2.00 D. S. ⊃ – 1.50 D. cyl. axis 180°
L. E. + 2.25 D. S. ⊃ – .75 D. cyl. axis 180°

As the second form gives periscopic shaped lenses, they should be given the preference.

How would you determine the focal length of a simple bi-convex lens with surfaces of equal curvature? Give all the practical methods you know of.

1. By neutralization with a concave lens.

2. By allowing rays of light from an object at least 20 feet away to pass through the lens and form an image on a screen, moving the lens closer to and farther from screen until the point is found where image is most distinct, and then measuring the distance from the lens to the screen.

3. By measurement of the curvature of each surface by the lens measure.

4. If the radius of curvature was known and the index of refraction of the glass from which the lens is made, we can find the focal distance by the following rule: divide the radius of curvature by twice the index of refraction less one, and the result will be the focal distance.

What is the composition of flint, crown and window glass? What are pebble lenses?

The composition of flint glass is as follows:

Silica	50	parts
Lead	30	"
Potash	10	"
Other ingredients	10	"
	100	parts

And crown glass:

Silica	70	parts
Soda	10	"
Lime	10	"
Other ingredients	10	"
	100	parts

Window glass is similar in composition to crown glass, but not quite so good quality.

Rock crystal or quartz is a product of Nature, and when cut into a slab or ground to form a lens is called a pebble.

Pebble lenses should be clear and free from striæ, specks and flaws and should be axis cut.

A prescription calls for $+ 1 \bigcirc + 50 \times 135$ *in toric lenses, minus 6 base curve. What will the lens measure show on two surfaces?*

On the concave surface towards the eye − 6 D. in the 45th meridian and − 6.50 D. in the 135th meridian; on the convex surface + 7.50 in all meridians.

Sphero cylinders have two focal lines. What must be the condition so that these lines will have an actual existence?

The sphero cylinder must be convex and then rays of light passing through it will be made to meet at the focal distances of the two principal meridians in the form of focal lines.

What is the character of the two focal lines in a plano cylinder?

In the meridian of the axis, the surface of the lens is plano and there would be no action on light. In the meridian at right angles to the axis the rays would be refracted to a focal line at the principal focal distance of this meridian, the line being in the same direction as the axis.

The following glass is called for: + 4.5 sph. ⊃ − 3 cyl. axis 45°. What will the measurements be if this is made up as a toric on a 6-base curve?

This will depend upon whether it is desired to have the 6 D. base curve on the concave or the convex surface.

If the base curve is convex we would have + 6 D. in the 135th meridian and + 9 D. in the 45th meridian, and the inner surface a − 4.50 D. curve.

If the base curve is concave, − 6 D. in the 45th meridian and − 9 D. in the 135th meridian, and the outer surface a + 10.50 D. curve.

What is the effect produced by decentering and what is the rule governing the same?

When a ray of light passes through the peripheral portion of a lens it is bent the same as if a prism was used, the prismatic effect increasing with the distance from the optical center.

To produce the effect of a prism with its base in a certain direction, a convex lens is decentered in that same direction and a concave lens in the opposite direction. For example to assist convergence a convex lens is decentered in towards nose and a concave lens decentered out towards temple.

The amount of prismatic power that may be developed by decentering of a lens, depends upon its strength and the amount of decentering, and this can be best illustrated by the prism diopter system of numbering.

Since a + 1 D. lens decentered 1 cm. produces a prismatic power of 1 $\triangle$;

And if P represents the prismatic power desired, D the dioptric power of the lens, and C the decentration in centimeters;

$$\text{then } P = D \times C \text{ or } C = \frac{P}{D}$$

For example if a + 4 D. lens be decentered 5 cm., then

$$P = 4 \times 5 = 2.0 \triangle$$

Or if the effect of 1 $\triangle$ is desired with a + 5 D lens, the amount of decentration would be

$$C = \tfrac{1}{5} \text{ cm. or 2 mm.}$$

What is a mobile or rotary prism?

When two prisms are placed in apposition, with base of one to the apex of the other, there will be neutralization if they are of equal strength. If these prisms are kept in apposition and revolved in opposite directions, they will produce the effect of a single prism, gradually increasing in strength until the bases of the two prisms come together, when the effect will be equal to the combined strength of the two prisms, as was first pointed out by Sir John Herschel, an illustrious English astronomer, who died in 1871.

The rotary prism consists of two superimposed prisms of 15° each, mounted in a cell of the size of a trial lens. By means of a milled-head screw these prisms are made to revolve against each other. When the base of one lies over the apex of the other, there is neutralization, and the indicator points to zero. As the screw is turned and the prisms begin to rotate, prismatic power is developed as shown by the indicator, 2°, 4°, 6° up to 30°,

the full power being reached when the bases of the two prisms are in apposition.

This rotary prism can be used in a trial frame and can be placed so as to present the base of the increasing prism up or down, in or out.

Give all the curves of a bifocal lens, the distance lens being 2 D. S. ⊃ − 1 D. cyl. 90° and the power of the segment being + 2 D. What difference would there be if the index of refraction of the glass used was 1.50 and 1.60 respectively?

The curvature of the two surfaces of the distance lens would be as shown by the formula. The segment would be attached to the spherical surface, and would show a − 2 D. curve on the inside and a + 4 D. curve on the outside.

When we say a − 2 D. curve or a + 4 D. curve we usually mean a curve that will produce − 2 D. power or that will show + 4 D. power; but as a matter of fact, in order to produce − 2 D. power, the radius of curvature must be 10 inches; and in order to produce + 4 D. power, the radius of curvature must be 5 inches, or in other words, the focus is twice the radius.

The above figures apply only in case the index of refraction of the glass is 1.50. If the glass used had an index of refraction of 1.60, then the radius of curvature necessary to produce + 4 D. power would be 5.45 inches.

The standard formula to find the focal length of a lens is as follows:

$$F = \frac{rr^1}{(r + r^1)\ (u - 1)}$$

Substituting figures of the above case

$$20 = \frac{-10\ r}{(-10 + r)\ .6} = \frac{-10\ r}{-6. + .6r}$$

Clearing of fractions we have

$$-120 + 12\ r = -10\ r$$
$$-120 = -22\ r$$
$$r = +5.45 \text{ inches.}$$

An anisometrope wears on the right eye a + 2 and on the left eye a − 2; his glasses are centered properly for distance; what is the nature of the prismatic action of the lenses when he looks at a nearby object?

As convergence comes into play and he looks at a near object the visual lines pass in each lens slightly to the inner side of the optical center.

For the right eye as he looks through a convex lens inside of its center, the prismatic effect produced is that of base out. For the left eye looking through a concave lens at its inner side, the effect is prism base in. As the lenses are of the same strength the prismatic effect produced will be equal in each eye, and one will neutralize the other.

Name and describe eight subdivisions of heterophoria. Draw a diagram illustrative of each condition.

Exophoria, in which there is a tendency to deviation outward, and the test shows the image of right eye to the left.

FIG. 24

Esophoria, in which there is a tendency to deviation inward, and the test shows the image of right eye to the right.

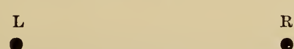


FIG. 25

Right Hyperphoria, in which there is a tendency for the right visual line to deviate above the left. The test shows the image of right eye to be below the left. (See Fig. 26, page 138.)

Left Hyperphoria, in which there is a tendency for the left visual line to deviate above the right. The test shows the image of right eye to be above the left. (See Fig. 27 below.)

FIG. 26

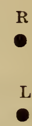


FIG. 27

Right Hyperexophoria, in which there is a tendency for the right visual line to deviate upwards and outwards.

The test shows the image of right eye to be below and to the left.

FIG. 28

Right Hyperesophoria, signifying a tendency for the right visual line upward and inward. The test shows the image of the right eye to be below and to the right.

FIG. 29

Left Hyperexophoria, a tendency of the left visual line upward and outward. The test shows the image of right eye above and to the left.

FIG. 30

Left Hyperesophoria, a tendency of the left visual line upward and inward. The test shows image of right eye to be above and to the right.

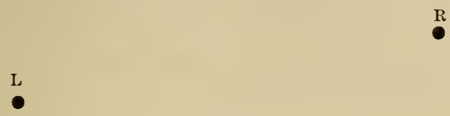


FIG. 31

Explain how an eye can have normal visual acuity and be ametropic.

In hypermetropia and hypermetropic astigmatism, if of not too high degree and in young persons, the action of the accommodation would neutralize the deficiency of refractive power or axial length, and maintain the acuteness of vision at the normal standard. This imposes an unnatural tax upon the ciliary muscle and leads to asthenopia.

Is there any advantage in correcting an ametropia when visual acuity is normal?

Yes, in order to lessen the unnatural strain upon the accommodation, and relieve the headache and other symptoms of asthenopia which are otherwise likely to occur.

Why is it desirable to know the far and the near point of vision?

The far point in emmetropia is at infinity, in hypermetropia beyond infinity, and in myopia at a certain finite distance; hence a knowledge of the far point indicates the character of the refraction.

The position of the near point represents the amplitude of accommodation, and indirectly by comparison with the normal standard at the particular age shows approximately the condition of the refraction. In hypermetropia and presbyopia the near point is of importance as showing the impairment of accommodation and the necessary help that must be afforded by convex lenses.

What is the relation, if any, of heterophoria to heterotropia? Explain fully.

Heterophoria is a tendency to a departure from the normal parallelism of the visual lines, while heterotropia is an actual deviation. Heterophoria is a latent strabismus, while heterotropia is a manifest condition.

What influence, if any, has the correcting of errors of refraction on muscular deficiencies?

When esophoria occurs in connection with hypermetropia, and exophoria with myopia, the convex lenses in the first case tend to correct the esophoria, and the concave lenses in the second case, the exophoria.

When, however, esophoria is found in connection with myopia and exophoria with hypermetropia, which is contrary to the usual relation, then the convex lenses needed to correct the hypermetropia would aggravate the exophoria, and the concave lenses in myopia would act similarly on the esophoria.

What muscles are taxed in (*a*) *abduction,* (*b*) *adduction,* (*c*) *sursumduction? Explain fully.*

Abduction is accomplished mainly by the action of the external recti muscles, which is, however, reinforced later by the two obliques. Hence we would say it is the external rectus that is taxed.

Adduction is accomplished mainly by the action of the internal recti muscles, reinforced later in the act by the superior and inferior recti. We would say it is the internal rectus that is taxed.

In sursumduction the vertical muscles are taxed, the superior rectus and inferior oblique of one eye being antagonized by the inferior rectus and superior oblique of the other.

The centers of a pair of — 3.25 D. spheric lenses mounted in spectacles are found to be 2 mm. farther apart than the pupillary centers of the wearer; what prismatic correction has he been wearing?

The rule is that for every decentration of 10 mm. there will be as many degrees of prismatic power developed as there are diopters of refractive power in the lens. Therefore, a decentration of a 3.25 spherical lens 10 mm. would make a prismatic effect of 3.25.

Now as the pupillary distance of the spectacles is 2 mm. farther apart than should be there is a decentration of 1 mm. for each eye, representing a prism of 0.325° for each lens, and as it is a concave lens and the decentration is outward, the base of the prism is in. This is less than one-third of a degree for each eye.

An eyeglass mounting containing the lens correction,

Right—5.00 D. cyl. × 180°

Left—3.00 D. cyl. × 180°

has become bent in such a manner that the wearer is looking through the right lens 3 mm. above the center and through the left lens 2 mm. below the center; what is the resulting imbalance expressed in prism diopters?

A cylinder if decentered in the direction of its axis would show no prismatic power, but in the direction at right angles to its axis the same prismatic value as a sphere of similar strength. Therefore, in this case we have a − 5 D. sphere decentered downwards 3 mm., and a − 3 D. decentered upwards 2 mm. with the resulting prismatic values as follows:

O. D. 1½ △ base up

O. S. 3/5 △ base down

or a total prismatic power of a little over 2 △.

In which position should the apex of the prism be placed to tax the strength of the external rectus muscle?

The apex of a prism calls a muscle into action and taxes its strength; therefore in this case the apex should be out.

Explain the cause of separation of the corneal images of the keratometer targets.

If the mires are placed in the meridian of greatest refraction so that the reflected images are just in contact, there will be a

separation when the instrument is turned to the meridian of least curvature.

What significance may be attached to an improvement in vision that is obtained by the pin-hole disk?

If impaired vision is due to opacities or diseased conditions, no improvement follows the use of the pin-hole disk or any other test. But if improvement in vision is afforded by the pin hole, the impaired vision is shown to be due to refractive error and imperfect focusing upon the retina and we can expect an equal improvement from lenses.

For what purpose is the double prism found in some trial cases used, and how is it used?

It is one of the tests for muscle imbalance.

It is placed over one eye while the patient looks at the light. Care must be taken that the line of separation between the two prisms is directly in the line of vision, in which case two lights will be seen by this eye, one above the other.

When the other eye is uncovered a third light will be seen, the position of which will show if any heterophoria is present, and its character. If midway between the two images and in the same vertical line, there is no imbalance.

If the middle image deviates to the same side esophoria is present; if to the opposite side, exophoria. If it moves up, hyperphoria of the other eye; if it moves down, hyperphoria of this eye.

For the detection of insufficiencies of the oblique muscles the patient looks at a straight line, which is doubled by the prism, the two lines being parallel to each other. When the other eye is uncovered a third line will be seen between the two and should be parallel with them. If this middle line tilts in either direction cyclophoria is shown.

Looking at a small object which is 4 meters distant to what extent will that object seem to be displaced if a prism of a power of 4 prism diopters is placed before the eye? Explain the reasoning.

A prism diopter deviates a ray of light 1 cm. for each meter of distance. Hence the deviation at 4 meters would be 4 cm. and if the prism was 4 △ the deviation would be 16 cm., which is the answer.

What is the size of an object 5 meters away that forms on the retina of a hyperope of 3 D. an image 5 mm. in diameter?

The proportion would be as follows: As 5000 mm. is to the size of the object, so is 14 mm. to 5 mm. To make the calculation the distance of the object must be multiplied by the size of the retinal image, and the quantity obtained divided by the distance of the nodal point from the retina.

$$\frac{5000 \text{ mm.} \times 5 \text{ mm.}}{14 \text{ mm.}} = 1786 \text{ mm.}$$

The completed proportion would be

Size Image		Size Object		Distance Nodal Point		Distance Object
5 mm.	:	1786 mm.	: :	14 mm.	:	5000 mm.

What direction must rays of light take in entering a hyperopic eye to focus on the retina?

With the accommodation at rest the rays must be convergent in order to focus upon the retina of the hypermetropic eye; and they are made so by the action of the convex lens that is placed before the eye to correct its defect.

What direction must rays of light take in entering a myopic eye to be focused on the retina?

The rays of light must be divergent in order to focus upon the retina of the myopic eye, and they are made so by the action of the concave lens placed in front of the eye to correct its defect.

A young hyperope, having normal acuteness of vision, either with or without + .50 D. spheric lenses, being subjected to the dynamic test is found to require + 1 D. spheric lenses to arrest motion of the shadow for all proximate distances up to 25 cm.; what lenses should be given him for reading?

In this case + .50 D. represents the manifest hypermetropia and + 1 D. the total hypermetropia, showing + .50 D. of latent defect.

As to what lenses should be given him for reading, we would say theoretically + 1 D., which would be the correction of the total hypermetropia. But in practice this might be modified by the symptoms of which the patient complains and the amplitude of accommodation he possesses. Many young hypermetropes with vigorous accommodation would be able to neutralize this amount of hypermetropia without any symptoms of asthenopia.

When the targets of an ophthalmometer overlap at angle 45 degrees and separate at 135 degrees what will be the axis of the + cylinder.

The meridian in which the targets overlap is the meridian of greatest refraction, and the meridian in which they separate the meridian of least refraction. Therefore, 45 degrees is the meridian of greatest refraction, and 135 degrees the meridian of least refraction; the latter is the meridian that needs the assistance of the convex cylinder, and hence its axis is placed at 45 degrees to get its refractive power at 135 degrees.

Explain at length the reasons for prescribing distance glasses and state the exceptions that may be made when ametropia is found.

Distance glasses are prescribed to improve vision or to relieve strain.

In the first class of cases we find *myopia*, in which concave lenses are necessary to restore distant vision to normal.

Also *hypermetropia* existing in a manifest form, especially in middle-aged people, where convex lenses are needed to afford good distant vision.

Also *astigmatism*, especially myopic, where concave cylinders are required for distant vision.

In the second class of cases, there are hypermetropia and hypermetropic astigmatism, where convex spheres and convex cylinders may be required for constant wear to relieve strain;

in slight degrees occurring in young persons with vigorous accommodation, there may be no symptoms of asthenopia and the constant wearing of glasses may be deferred.

How should a presbyope be tested for muscle imbalance at 14 inches; if this imbalance is found, what correction, if any, would you give?

The near test should be made with the reading glasses before the eyes. The dot and line may be used in connection with a vertical prism but we prefer to use the Maddox rod and a small point of light 14 inches away, such as can be obtained from a chimney with an iris diaphragm.

Esophoria is but seldom found and calls for no correction.

Exophoria is much more common, but is to be corrected only in a small percentage of cases. This may be accomplished by decentering the convex lenses inwards, or if more decided prismatic assistance is needed, by combining prism, bases in with the spheres, as a rule correcting not more than one-half the exophoria.

In a compound lens; a + 2 sphere combined with a + 1 cyl. axis 90°, at what distance from the lens will the image of a distant point have the form of a vertical line, and at what distance will it have the form of a horizontal line?

The power of this lens would be + 3 in the horizontal meridian and + 2 in the vertical meridian. The first focus, therefore, would be that of the horizontal meridian which would be located at 13 inches, in the form of a vertical line; and the second focus would be that of the vertical meridian which would be located at 20 inches in the shape of a horizontal line.

What is the principle of the construction of the ophthalmometer?

Two bright bodies called mires are reflected from the surface of the cornea under examination, after first being doubled by the prisms in the telescope. The observer looking through

the telescope sees the corneal reflections of these mires. He considers only the two central mires, which he adjusts so that they are just in contact in the meridian of least refraction. As the instrument is turned to the meridian at right angles, the mires will overlap, in this way showing how much one meridian exceeds the other in curvature. The guide lines of the mires indicate the location of the two principal meridians.

The instrument shows positively the absence or presence of corneal astigmatism, the amount of same and the position of the axis of the correcting cylinder.

How is it possible to tell whether a case is compound, simple or mixed astigmatism?

In the use of the retinoscope if one meridian was found to be emmetropic and the other ametropic the case is simple astigmatism. If both meridians are hypermetropic or myopic, varying in degree, compound astigmatism. If one meridian is hypermetropic and the other myopic, mixed astigmatism.

Or by the trial case examination, if a plano cylinder was required, the case is one of simple astigmatism. If the sphere is called for in addition to the cylinder, the case is compound or mixed, according to whether the signs are alike or unlike.

If a prism is placed in front of the eye, base downward, what will be the effect on the eye behind that prism?

As the eye turns toward the apex of a prism in this case the eye will turn upwards.

What is an ophthalmometer? Describe the principles upon which it is constructed and state some of the reasons why its readings cannot in all cases be relied upon.

The ophthalmometer is an instrument devised to measure the corneal curves and consists essentially of a telescope and a set of mires. The latter are adjusted for the meridian of least refraction and then the instrument is turned 90° to the meridian of greatest refraction and the difference between the curvatures of the two meridians is shown at once.

As the scope of the instrument is limited to the measurement of the curvature of the anterior surface of the cornea, it is evident that it cannot be relied upon in all cases of astigmatism, because in a limited number of cases there is a certain amount of lenticular astigmatism which must be taken into account in estimating the astigmatism of the eye as a whole. This lenticular astigmatism may be static or dynamic, either of which changes the error as indicated by the ophthalmometer. This explains why the eye will not always accept the cylinder representing the corneal astigmatism as measured by the ophthalmometer.

What is an ophthalmometer?

An instrument which by means of reflected images measures the curvature of the cornea in its several meridians, and is used in the detection and measurement of astigmatism. It makes an objective test.

What is a perimeter?

An instrument to measure the extent of the field of vision and to detect the existence of scotomata. It makes a subjective test, but as it has reference only to indirect vision it is of no special value in the fitting of glasses.

What is a phorometer?

Consists of two prisms, one before each eye, which rotate in conjunction, and it can be used not only to detect any muscle imbalance, but to measure it at the same time.

If a person wore a 3° prism, base out *over one eye and a 2° prism, base* in, *over the other, what would be the effect of the same?*

The effect of a prism base in is to neutralize the effect of a prism base out, and hence in this case the prism base in would neutralize 2° of the prism base out, and the result would be a prism of 1° base out.

If the far point with + 4.5 sphere is 60 cm., and with a + 2.5 sphere it is at 30 cm., what is the refractive condition?

A far point of 60 cm. would represent a myopia of 1.66 D., and if this condition is artificially produced by a + 4.50 D. lens then we must assume the eye is hypermetropic to the extent of the difference between them, viz., 2.84 D.

A far point of 30 cm. would indicate a myopia of 3.33 D., and if such myopia is artificially produced by a + 2.50 lens, then we infer that the refraction of the eye must be myopic to the extent of the difference between them, or .83 D.

A boy, 10 years, has a visual acuity of 6/60; with a + 3 sph. he can see 20/20, and the near point is at 33 cm. What is probably the refractive error in this case?

In a case like this, where an acuteness of vision of only one-tenth is raised to normal by a convex lens, the refractive error is undoubtedly hypermetropia. But whether this + 3 D. sphere represents the full correction is another question, on which we have no information. If normal vision is reached with this lens the optometrist should not stop here, but continue with stronger lenses as long as a vision of 20/20 is maintained, because the measure of the error is the strongest convex sphere the patient can be induced to accept for distance.

Taking up the question of the optics of such an eye from a theoretic standpoint, if the + 3 D. lenses produced a near point of 33 cm. they would seem to fall far short of a full correction. This near point indicates an accommodation of 3 D., whereas the normal amplitude at this age is 14 D., showing a deficiency of 11 D., which added to the 3 D. would make 14 D. as the measure of the defect in this eye.

Looking at the matter from a practical standpoint, in the presence of such a high degree of hypermetropia, it would scarcely be possible to raise the vision to normal by a + 3 D. lens, or, for that matter, by any lens.

A patient assisted by 1 D. lenses reaches the punctum proximum at 33 cm.; what is his amplitude of accommodation?

This punctum proximum represents an amplitude of accommodation of 3 D. If this was reached by the assistance of 1 D. lenses, then the patient's natural amplitude of accommodation is 2 D.

In the above case, what proportion of the accommodation is held in reserve when + 1.5 D. lenses are used for reading at 33 cm.?

In order for an emmetrope to read at 33 cm., 3 D. of accommodation is necessary, of which amount 1.50 D. is supplied by the convex lenses, and the other 1.50 D. by the accommodation itself. As this patient is said to have an amplitude of accommodation of 2 D., the amount held in reserve is .50 D.

A certain person requires for distance a — 1.50 sph., and has an amplitude of accommodation of 6 D. With what glass will he see most clearly at a distance of 20 inches, the — 1.50 or a + .50?

If a + .50 D. lens is placed in front of this person, who is myopic to the extent of 1.50, his myopia is increased to 2 D., and hence this specified distance of 20 inches would represent his far point where he would be able to see without effort of accommodation. If, on the other hand, the — 1.50 D. lenses were used, his amplitude of accommodation would be reduced to 4.50 D., of which he would require 2 D. to see at 20 inches, leaving 2.50 D. in reserve.

Whether he would be able to see most clearly at 20 inches without any effort of accommodation, as in the one case, or at the expense of less than half his available accommodation, as in the other case, is a point that cannot be determined by any rule.

What is the function of the retina?

To receive the images of external objects as they are focused by the refracting media, and transfer the impressions it thus receives through the optic nerve to the brain.

If patient's vision is 20/20 and he can see all the lines on the clock dial distinctly and equally, and can also read the very smallest

print at his ordinary reading distance, what refractive error can he have?

He might have a small amount of hypermetropia, which in a young person is readily overcome by an active accommodation. It is also likely that he might have a slight hypermetropic astigmatism, but not possible to have myopia or myopic astigmatism.

At what distance from the patient must the test card be placed so that light coming from it will be practically parallel?

By universal consent it has been agreed that the test card shall be placed at 20 feet and that rays therefrom shall be assumed to be parallel for our purposes in testing.

Strictly speaking, rays from 20 feet have a divergence of 240 inches, which is equal to one-sixth of a diopter, and hence lenses fitted at this distance might be that much too strong in convex and too weak in concave.

When does the stenopaic slit act best?

We would say in myopic astigmatism of marked degree, or in hypermetropic astigmatism when a cycloplegic has been used, as otherwise the accommodation would make its results uncertain.

What is effect of pupillary distance of lenses too wide or too narrow?

When too wide the effect of a prism base out in convex lenses, and base in with concave lenses.

When too narrow the effect of prism base in with convex lenses, and base out in concave lenses.

When should the pin-hole test be used?

In all cases where the visual acuity is much impaired. It would be of no value in cases where the acuteness of vision is normal, or nearly so.

With the vertical lines in the fan the blackest, the others being dull, blurred or gray, what is the axis of the correcting cylinder, and what is the abnormal meridian?

If the vertical lines are clearest, it is the vertical meridian of the eye that is abnormal, and as the axis of the cylinder is placed in the same direction as the indistinct lines, in this case the axis would be horizontal, and in this position would correct the abnormal vertical meridian.

What is the purpose of the test with the Maddox rod? What is tested when the rod is vertical?

The purpose of the Maddox rod is to form in the eye a retinal image that is so dissimilar in size, shape and appearance from the other that the natural desire for fusion is suppressed, thus giving the eyes over to the action of their muscles and allowing any imbalance to become manifest.

When the rod is vertical the test is made for hyperphoria.

State how you would measure the amplitude of accommodation and the power of convergence?

By measuring the closest possible point of vision with the smallest type and transposing the same into diopters will show the amplitude of accommodation.

For instance, if 10 inches was the nearest possible reading point, the amplitude of accommodation would be 4 D.

The power of convergence is measured by the strongest prisms bases out which the eyes are able to overcome and maintain single vision of a point of light.

In case of ametropia, by what means may a prognosis of an improvement in vision be made without the use of lenses?

By means of the pin-hole disk. In cases where the vision is greatly impaired, if the pin-hole produces a decided improvement in vision, we can assume that the impairment of vision is due to ametropia and that an equal or even greater improvement

can be expected from lenses. Whereas if the pin-hole fails to improve vision the impairment is probably due to disease and glasses would be useless.

What is the rule for correcting hypermetropia and myopia (a) when the patient is fifty years of age ; (b) when the patient is eighteen years of age? What is the rule in each case if heterophoria also is found?

(a) When patient is fifty years of age there is little danger to fear from the accommodation, and hence the manifest error as found could be safely corrected, inclining to the stronger convex lenses in hypermetropia and the weaker concave lenses in myopia.

(b) At eighteen years of age in the presence of an active accommodation and probably more or less spasm, we cannot always give the convex lenses as strong in hypermetropia as we might like on account of the objections of the patient, and yet even at this age our effort always is to give convex lenses as strong and concave lenses as weak as possible.

Esophoria in connection with hypermetropia would indicate a stronger convex lens, while exophoria would call for a weaker one.

Esophoria in connection with myopia would indicate a weaker concave lens, and exophoria a stronger one.

Describe two methods of measuring (a) adduction, (b) abduction, (c) sursumduction. State the theoretic value of these tests.

By prisms from the trial case where they must be removed and replaced by stronger ones, and by the rotary prism where the strength can be gradually increased without removal from before the eye.

(a) Adduction is measured by the strongest prisms bases out which the eyes are able to overcome.

(b) Abduction by the strongest prisms bases in.

(c) Sursumduction by the strongest prisms bases up or down.

Theoretically these tests are supposed to show the full power of the different muscles.

With vision of 20/20 what conditions of refraction may exist?

Emmetropia or slight hypermetropia or slight hypermetropic astigmatism.

With vision of 20/20 what kinds of ametropia are eliminated?

Myopia and high degrees of hypermetropia and astigmatism.

If vision at 20 feet is improved by a − .50 D. lens what refractive conditions may exist?

There may be a slight degree of actual myopia or the refraction may be emmetropic or hypermetropic, in which a spasm of accommodation will cause a concave lens to be accepted.

A hyperope with exophoria aged twenty has 20/20 vision with + 1 D. Is this the proper correction?

We are not told whether this + 1 D. is the strongest convex lens that would be accepted, but even if it is, in the presence of exophoria, it probably does not represent the full amount of the hypermetropia, because the convergence is under strain to overcome the tendency to divergence. In order to measure the full refractive error there must be relaxation of both convergence and accommodation, and this can be accomplished by combining prisms bases in with the convex lenses, when it will probably be found that a stronger than + 1 D. will be accepted.

With a prism base down before the left eye the upper image is to the left of the lower image. What name is given to the condition? Why does the eye deviate? Where should the base of the correcting prism be placed?

The condition is esophoria and diplopia homonymous. The eye deviates inward either from excess of convergence or weakness of divergence. The correcting prism is placed base out.

What is the amplitude of accommodation of a hypermetrope of 2 D. whose near point is at 10 inches?

The emmetropic eye in order to see at 10 inches will use 4 D. of accommodation, but here there is an additional 2 D. required to overcome the hypermetropia, hence in this particular case the amplitude of accommodation is 6 D.

If a hypermetrope of 2 D. has his near point of 16 inches, what is the amount of the presbyopia and what is the correction for near use?

The near point of 16 inches shows an amplitude of accommodation of 2.50 D. For comfortable reading the person should possess 5 D. of accommodation; hence there is a deficiency of 2.50 D. We are told there is a hypermetropia of 2 D., and then the other .50 D. must be due to presbyopia of this amount.

The correction for near use would be + 2.50 D., covering both the hypermetropia and the presbyopia.

We are told to subtract the far point from the near point for the amplitude of accommodation in myopia, and to add them together in hypermetropia. What is the explanation of this rule?

In myopia the amplitude of accommodation seems to be greater on account of the excess of refractive power of the myopic eye; hence in order to find the actual amplitude of accommodation we must subtract the amount of myopia.

In hypermetropia the amplitude of accommodation seems to be diminished on account of the deficiency of refractive power of the hypermetropic eye; hence in order to find the real amplitude of accommodation we must add the amount that is used to overcome the hypermetropia.

Which tint of glass is best for eyes that are bothered by sunlight?

There is a difference of opinion on this point. In the majority of cases smoked glasses will afford the most relief, and they have the advantage of not producing any false color effects. In a certain class of cases blue glasses are to be preferred. because they absorb the irritating and stimulating red rays. Of late years amber glasses have been recommended, because they

suppress the chemical rays and, while softening dazzling reflections, do not diminish the amount of light admitted to the eye. The very latest, and perhaps the best tinted lenses are Crookes.

Explain why in cases of ametropia the pin-hole disk always improves vision.

If a lighted candle be placed in front of a thin metallic plate having a small aperture or pin-hole, an image of the flame will be formed upon a screen of white paper or cardboard that is placed back of it. Most of the rays proceeding from the candle will be intercepted by the plate, but one ray from each point of the candle will pass through the pin-hole, and as they pass they cross and form an inverted image. The ray from the tip of the flame forms the tip of the inverted image, and the ray from the bottom of the candle forms the top of the image. A camera can be constructed upon this principle and photographs made without the use of a lens.

When impaired vision is due to the imperfect focusing of an ametropic eye the pin-hole disk, by cutting off so many of the rays, nullifies the refractive power of the eye, and the retinal image is formed by the pin-hole upon the principles just described.

The pin-hole in like manner destroys the effect of any lens, no matter how strong, a fact that can be easily demonstrated. Take a moderately strong convex lens and hold it close to the eye, when the letters on the test card across the room will be hardly discernible or entirely blotted out. As soon as the pin-hole disk is imposed the refractive power of the lens is destroyed and the letters are as clearly seen as the naked vision of the eye will allow.

If you had a patient forty-five years of age wearing for distance O. U. — 1 D. sph., with which his near point is 11 3/7 inches, what will be his correction for near use?

This near point represents an amplitude of accommodation of 3.50 D. Inasmuch as this is accomplished through his distance glasses of — 1 D. his natural accommodation without glasses

would be 4.50 D. This would probably suffice for comfortable reading without assistance, but theoretically with the idea that the amplitude of accommodation should not fall below 5 D. a + .50 D. lens would be the proper correction for near use.

Why is it that we cannot tell from the test with the ophthalmometer the full astigmatic error of the eye?

Because it measures only the corneal astigmatism and is unable to reach the astigmatism that may be located in the crystalline lens.

In using the ophthalmometer the mires are brought into exact contact in one principal meridian, and are then found to overlap in the other principal meridian; what cylinder is indicated, convex or concave, and on what axis?

If we knew the normal curvature of this particular cornea for the first principal meridian where the mires were in exact contact then an overlapping would show a myopia in the second meridian. Or if this second meridian where the overlapping occurred was normal then the first meridian is hypermetropic.

But as a matter of fact we do not use the ophthalmometer to ascertain whether the cylinder should be convex or concave, but to measure the difference in power between the two principal meridians (which is the amount of astigmatism) and the location of these two meridians.

If a convex cylinder is required its axis will correspond to the meridian of overlapping; if a concave cylinder, to the meridian which showed exact contact.

When in the fogging test the lines which are most blurred are the vertical lines, in which meridian of the eye is the refractive error, the vertical or the horizontal?

Ordinarily the answer would be in the horizontal meridian, but this is true only in case of a hypermetropic astigmatism in which the fogging lens caused complete relaxation of the accommodation.

It is possible that the horizontal meridian may be emmetropic, and if the ciliary muscle failed to relax in response to the fogging lens it would be made artificially myopic and cause the vertical lines to appear indistinct, when really the hypermetropic error would lie in the vertical meridian.

In a static eye fully corrected with a − 1 sph. combined with − 50 cyl. axis 90°, where will be the neutral points of the two principal meridians of the eye?

This correction would indicate a myopia of 1 D. in the 90th meridian, and of 1.50 D. in the 180th meridian; and the neutral points would be at 40 inches and 26 inches respectively.

Convergent light entering the eye comes to an exact focus; what kind of an eye is it? What will be the focus of far distant objects in such an eye?

The hypermetropic eye is the only form of eye adapted for convergent rays. If the accommodation was at rest the focus of parallel rays emanating from far distant objects would be behind the retina.

A person fifty years of age looking at an object 20 inches away with − 4 D. sph. ⊂⊃ + 5 D. cyl. axis 90°, accommodates 1 D. What is the reading and distance correction?

In order to look at an object 20 inches away 2 D. of accommodation must be used, but as this person accommodates only 1 D. we must conclude that the other 1 D. is supplied by the uncorrected myopia. Hence the distance correction would be:

− 5 D. sph. ⊂⊃ + 5 D. cyl. axis 90°

For near vision we would add about + 2.50 D., which would make the reading correction:

− 2.50 D. sph. ⊂⊃ + 5 D. cyl. axis 90°

Name the several methods of determining the nature of a refractive error.

Trial case and test types, retinoscopy, ophthalmoscopy, refractometer or optometer, Scheiner's test, chromatic test, measuring amplitude of accommodation and stenopaic slit.

In looking through a prism which way does the eye turn and in which direction is the object seemingly displaced?

The eye turns toward the apex of the prism and the object is apparently displaced in the same direction.

In a certain lens the eye first looks through a point 1 mm. above the optical center of the lens and then through a point 1 mm. to the side of the optical center. The deviation of a distant object is greater in the first case than in the second. What kind of a lens is it?

Since there is greater deviation when looking upward than when looking to the side there must be greater curvature in the vertical meridian than in the horizontal. This would indicate a convex sphero-cylindrical lens, with the axis of the convex cylinder horizontal.

Describe the optical principles involved in placing prisms before the eyes for the purpose of ascertaining the powers of abduction and adduction?

In orthophoric eyes the image is assumed to fall on each macula without muscular effort. When a prism is placed before one or both eyes, the rays of light are turned out of their course and bent toward the base of the prism. Under such circumstances the image would fall on the retina away from the macula and produce diplopia, except that the eye as far as it is able involuntarily turns toward the apex of the prism in order to keep the image on the macula and prevent diplopia.

Therefore, when the prism is placed base in, the eye turns out in compensation, and the strongest prism base in which the external recti muscles are able to overcome and maintain binocular vision will represent the power of abduction.

Contrariwise, when the prism is placed base out, the eye involuntarily turns in as far as it is able, and the strongest prism base out which the internal recti muscles are able to overcome and maintain binocular vision will represent the power of adduction.

A hypermetrope of 2 D. has an amplitude of accommodation of 4 D. Make the calculation for lenses to be used in reading at 33 cm. so that one-fourth of the accommodation may be held in reserve.

If it is desired to hold in reserve one-fourth of this 4 D. of amplitude of accommodation, there will be only 3 D. of accommodation available for use, of which 2 D. will be taken to overcome the hypermetropia, leaving 1 D. for use in reading. But as 3 D. is required for use at 33 cm., the accommodation must be suplemented by a + 2 D. lens.

What is the practical value of the pin-hole disk and of the stenopaic disk?

The value of the pin-hole disk is to determine in any case of greatly impaired vision whether it is due to an error of refraction that can be corrected by lenses or to a diseased condition that is beyond optical assistance.

Of the stenopaic disk to locate the two chief meridians of the eye, that of best and of poorest vision, and by means of lenses placed before it to measure the refraction of those two meridians.

A patient looks at a light 20 feet away and a prism strong enough to produce double vision is placed base up before the right eye; state the defect and its amount when the lower light is located to the left and a prism of 4° before one eye is required to place both lights in a vertical line, and what will be the position of the 4° prism?

If prism is base up before right eye, the lower image would belong to this eye, and if located to the left would indicate exophoria, to the extent of the correcting prism which is placed base in.

On which side of the median line will the streak of light produced by the Maddox rod before the right eye appear in esophoria.

Right side.

What is meant by the term refraction? And what is meant by the term refraction of the eye?

Refraction means the bending of rays of light as they pass obliquely from one medium into another of different density.

Refraction of the eye is the action of the dioptric media of the eye on the light that enters it in bringing it to a focus either on or off the retina.

It signifies the optical condition of the eye, whether emmetropic, hypermetropic or myopic.

The refraction of the vertical meridian is 1.50 D. hypermetropic and of the horizontal meridian .25 D. myopic. What is the prescription required?

+ 1.50 D. cyl. axis 180° ⊂ – .25 D. cyl. axis 90°,

or,

+ 1.50 D. sph. ⊂ – 1.75 D. cyl. axis 90°.

What is the refractive condition of an eye which requires a + 1.25 cyl. axis 60° for reading and a – 1.25 cyl. axis 150° for distance?

Simple myopic astigmatism of 1.25, in connection with presbyopia of like amount.

The prescription for a certain eye is – .50 ⊂ – .25 cyl. axis 75°; what will be the dioptric power of the eye in its two principal meridians, assuming that 58 D. represents emmetropia?

As myopia acts in the way of increasing the refractive power of the eye, there would be 58.50 D. in the 75th meridian and 58.75 D. in the 165th meridian.

Give some description of the Risley Prism and how it is used?

This consists of two 15° prisms mounted in two cells, placed in apposition and controlled by a milled head screw. When so placed that the apex of one prism lies against the base of the other, their prismatic power is neutralized, and their only effect is that of a thick piece of glass. As the milled head is turned and the prisms are rotated away from the position of neutralization, the effect of a single increasing prism is produced, which reaches its greatest power (30°) when the two bases coincide.

When the line on the prism points to zero on the scale in the vertical position, a horizontal prismatic power can be developed by rotation. When the line points to zero in the horizontal position, vertical prismatic power can be developed by rotation.

In any of these cases the amount of power base in, out, up or down, can be read off the scale.

The Risley prism can be used to measure the duction power of the various muscles.

The 180th meridian of one eye is 5 D. hypermetropic, and the 90th meridian 6 D. hypermetropic. If torics are prescribed, the convex curve of the same being + 8 D. sphere, what will be the dioptric power of the concave surface in the two principal meridians?

This can, perhaps, be best worked out and understood by diagrams.

The first diagram shows the desired power in each meridian.

+ 6 D.	+ 8 D. − 2 D. ——— + 6 D.
+ 5 D.	+ 8 D. − 3 D. ——— + 5 D.

The second diagram shows in order to maintain these powers unaltered, how much concavity must be added in each meridian, viz.: − 2 D. in the vertical meridian and − 3 D. in the horizontal meridian.

If a certain eye has a power in the 90th meridian of 54 D. and in the 180th meridian 53 D., what sphero cylinder must be prescribed to give emmetropia for distance, if, with the accommodation at rest, a perfect retinal image required the eye to have a dioptric power of 53.50 D?

If a dioptric power of 53.5 D. is assumed to represent emmetropia, then the vertical meridian which has a power of 54 D. shows an excess of dioptric power of .50 D., which means a myopia of like amount; and the horizontal meridian which has a power of .53 D. shows a deficiency of dioptric power of .50 D., which means a hypermetropia of like amount.

To correct this condition we must place a − .50 D. in vertical meridian to reduce it to 53.50 D., and a + .50 D. in horizontal meridian to raise it to 53.50 D., as follows: − .50 D. cyl. axis 180° ⊂ + .50 D. cyl. axis 90°, which is transposed to − .50 D sphere ⊂ + 1 D. cyl. axis 90°.

When the vertical lines on a clock dial are clear, and the horizontal are not, which meridian will require a concave cylinder to correct it?

The rule is to place the axis of the correcting cylinder in the same direction as the indistinct lines, which in this case would be horizontal.

In seeking the explanation of this, it must be remembered that the horizontal lines are seen by the vertical meridian of the eye and as they are indistinct in this case it must be because the vertical meridian is ametropic; hence we place the axis of the cylinder at 180° in order to bring the refractive power of the lens over the vertical meridian, which is the one calling for correction.

How is it possible to know with certainty that an eye when being tested has been brought out of the fog or not?

It is safe to assume the eye is out of the fog when the acuteness of vision has been raised to 20/20. However, it may then be too much out of the fog, which is something we want to avoid, and, therefore, we will try an extra + .25 or + .50 and see if it

blurs and how much. Or better still, we repeat the whole procedure, taking care to stop as soon as fairly normal vision is attained.

Which blurs the most, objects as seen by a hypermetrope, or as seen by a myope, and why?

This depends on the degree of ametropia and whether reference is made to distant or near objects. With equal degrees of defect, vision for distant objects would be more blurred in myopia, because the hypermetrope is able by means of his accommodation to neutralize his deficiency of refractive power and make vision normal.

Whereas in myopia the use of the accommodation (which is the only function we possess to influence the distinctness of the retinal image) would make the blurred vision still more indistinct.

But there are some cases of high hypermetropia in which vision is very much impaired, and the accommodation is unable to raise it to normal, probably on account of the undeveloped condition of the eyeball.

What is meant by the term "meridian of greatest refraction," and how is it known?

In regular astigmatism there are two principal meridians, one of greatest and one of least curvature at right angles to each other. In myopic astigmatism the meridian of greatest refraction is that meridian which shows the most myopia, and in hypermetropic astigmatism the one showing least hypermetropia. In the first case it is the meridian right angles to the axis of the concave cylinder; and in the second the meridian that corresponds to the axis of the convex cylinder.

It may be detected by the fogging method used in two ways:

Fog first a set of vertical lines and then a set of horizontal lines, and the meridian of greatest refractive power would correspond to the direction of the lines that can be seen with the strongest convex sphere.

Or fogging the whole astigmatic dial, it is in the same direction as the lines that first come out of the fog.

Or it can be found by the retinoscope which measures the refraction of each meridian in turn.

When are parallel lines as shown on astigmatic charts reliable, and when not?

These parallel lines radiate in all directions, and they are to be relied upon as a test for astigmatism only when the accommodation is at rest (as in fogging), as otherwise the patient would instinctively make an effort to clear the lines, and thus mask the astigmatism or lead to an incorrect diagnosis.

Which should be corrected first in retinoscopy, the spherical error or the astigmatic error, and what is the reason?

The writer thinks it is best to correct first the meridian of least refraction, and then the meridian of greatest refraction. The first would represent the spherical error and the difference between the two the astigmatic error.

When should a person with high astigmatism get normal vision with his correction, and when would this not be true?

Sometimes it is impossible in high astigmatism to afford normal acuteness of vision, and this is especially true if the error is not corrected until later in life. If, however, cylindrical lenses had been worn from an early age, and they needed changing as they usually do from time to time, we would expect the new lenses to give fair vision if there is not too much difference in the strength of the lenses or the position of the axis from the previous ones.

Where glasses had not been previously worn and the sensibility of the retina was blunted by the imperfect images focused upon it, vision with the cylinders will be more or less unsatisfactory, although we would expect it to improve with the constant wearing of the glasses.

How is the test for adduction usually made?

By prisms bases out gradually increased in strength. The strongest prisms with which single vision of a light can be maintained represent the power of adduction. This is a variable quan-

tity and ranges from 15° to 40° or higher, and can be greatly increased by exercise.

When two plus lenses of different power give equally good vision, why is the stronger one selected?

We presume that this has reference to the tests for distant vision in hypermetropia, in which the rule is to select the strongest convex lens the patient can be made to accept, for the reason that the stronger the lens, the more of the hypermetropia it corrects and the less effort on the part of the accommodation is required.

If a patient has astigmatism which requires a + 2 D. cylinder axis horizontal to correct, and you place a + 2 D. sphere before the eye, what artificial condition is produced?

The + 2 D. sphere corrects the hypermetropic meridian, but at the same time it blurs the emmetropic meridian and makes it myopic to the extent of 2 D. Therefore, the artificial condition produced is simply myopic astigmatism, at right angles to the original hypermetropic astigmatism.

What is the principal purpose of each of the following instruments: ophthalmoscope, retinoscope and ophthalmometer?

The ophthalmoscope, to examine the interior of the eyeball as to the presence or absence of disease, and if disease is present to determine its location and nature.

The retinoscope, to measure the refractive condition of the eye.

The ophthalmometer, to detect and measure corneal astigmatism as to its amount and the location of the two principal meridians.

Under what conditions may a person have an amplitude of accommodation of 3 D. and still have no range of vision?

When hypermetropia is present to an equal or greater amount.

If a patient has myopic astigmatism, under what conditions would a plus cylinder be proper to prescribe?

For reading after presbyopia has set in. For instance, if a patient wearing − 1 D. cyl. axis 180° reaches 45 years of age, when the addition of + 1 D. is needed for reading, the prescription would be + 1 D. cyl. axis 90°.

If light coming from a distance of 20 inches is exactly focused on the retina with a + 3 D. lens and with the accommodation at rest, what is the kind and amount of refractive error? How do you calculate the result?

Light coming from a distance of 20 inches has such a degree of divergence that requires + 2 D. lens to focus it upon the retina of an eye with the accommodation at rest.

If, however, as in this case, a + 3 D. lens is required, then we must assume that the extra + 1 D. represents a deficiency in the refractive power of the eye of that amount or in other words a hypermetropia of 1 D.

How would you test the strength of any particular ocular muscle with prisms?

By placing apex of prism over such muscle and finding strongest prism with which binocular vision can be maintained.

What is the main purpose of the ophthalmometer?

To determine the curvatures of the cornea, the location of the two principal meridians and the refractive power of each meridian.

If a person 50 years of age came to you wearing a pair of bifocals of which the power was 3.50 D., what error in the distance correction would you suspect?

We assume that + 3.50 D. is meant to indicate the power of the segments, in which case we would say the distance was under-

corrected; for the reason that at this age the segment scarcely exceeds 2 D. or in other words the presbyopia is seldom greater than this. Hence the 3.50 D. segments are correcting some of the hypermetropia, which should have been provided for in the distance lenses.

A child showing with the objective tests 5 D. of hypermetropia sees clearly with + 1.50 D. lenses, while anything stronger blurs the letters. What would you give and how would you handle the case?

This would depend somewhat on the age of the child and the symptoms of which he complains. As a rule children will bear fogging better than adults, therefore, if the child were quite young and the symptoms urgent, we would give + 2.50 D. for constant wear.

If the child was older and likely to object to the fogging, we would attempt to correct only the manifest hypermetropia at first with + 1.50 D. lenses, in the thought that after a while some of the latent defect would become manifest when the strength of the glasses could be increased. After these second glasses had been worn for a time, perhaps another increase could be borne, if the symptoms were such as to call for more relief.

What method would you employ to find the amount of latent hypermetropia? Can the latent be estimated from the amount of manifest?

I would employ the fogging method to estimate as far as possible the total hypermetropia, and the difference between that and the manifest hypermetropia would represent the latent.

Or if it was not possible to discover any latent error in this way, I would correct the manifest with the thought that under such correction some of the latent would gradually become manifest.

The amount of latent bears no constant relation to the amount of manifest error; in youth it is nearly all latent and in old age it is nearly all manifest.

If the internal recti muscles were weak, how would the prism exercise be given to make them stronger?

As the apex of the prism is always to be placed over the muscle to be exercised, the prisms in this case are to be placed bases out.

The first point is to ascertain the power of the internal recti and thus determine how far they fall below the normal standard, which is accomplished by means of prisms bases out, the strongest with which single vision of a light can be maintained. This may fall to 10° or less as compared with the normal power of convergence, which is from 20° to 30°.

Having found this strongest prism, it is divided between the two eyes and alternately raised and lowered. Each time the prisms are lowered the light is probably seen double momentarily, but is quickly brought into one by the action of the internal recti. The raising of the prisms allows these muscles to relax a little and get a slight rest, and their lowering calls the muscles into action again.

This alternate relaxation and contraction stimulates the innervation and circulation of the muscles, and it is soon found that stronger prisms can be overcome, and hence they are gradually strengthened as the increasing power of convergence will allow.

A myope is found to be wearing his spectacles each − 10 D. sphere tilted so that the right glass is 5 mm. above the center of his pupil and the left glass is 5 mm. below. What will be the effect on his vision and how many degrees would it displace the image at 3 meters?

According to the rule of decentration that there would be 1° prismatic effect for each diopter of refractive power when decentered 10 mm., there would be 5° prism power added to the concave lens in each eye. In the right eye the prismatic effect would be base down, which causes a displacement upward of object looked at, and in left eye base up causing displacement downward.

As the vertical muscles are comparatively weak and easily thrown out of balance, such tilting of the lenses would almost

certainly cause diplopia, unless there was a condition of right hyperphoria, which would be corrected by such position of the lenses.

Inasmuch as the above figures apply for each meter of distance, the displacement at 3 meters would be three times as great.

A person requires for the right eye alone — 6 D. sphere for distance and — 3 D. sphere for reading, but wants only one pair of spectacles. State the various ways in which this can be managed, and which method you prefer.

As the question states the glasses are required for the right eye alone, we must assume that the left eye is useless as an organ of vision, and the effect of the proper glass before the right eye can be obtained in one of several ways.

1. By using a reversible eyeglass frame with regular guards, or reversible spectacles with a C or X bridge, and placing a — 6 D. lens in one of the eyepieces of the frame and a — 3 D. lens in the other eye wire, which will allow the lens desired to be placed before the right eye at will.
2. By a frame fitted with — 6 D. lenses and a hook front fitted with + 3 D. lenses.
3. By a frame fitted with — 3 D. lenses and a hook front fitted with — 3 D. lenses.
4. By giving bifocals, with — 6 D. for distance and + 3 added for reading.

What is the effect of having strong lenses placed too far from the eye?

As a strong convex lens is moved away from the eye the object seems to approach and is magnified; as a concave lens is moved away the object seems to recede and is minified.

In testing an eye with the stenopaic slit and using a set of parallel test lines as the object of regard, how should these lines be arranged in reference to the direction of the slit?

Vertical lines are seen by the horizontal meridian of the

eye and horizontal lines by the vertical meridian; hence the lines should always be at right angles to the direction of the slit.

But as a matter of fact the card of test letters should be used in connection with the stenopaic slit and not the card of radiating lines.

On what principle are the sizes of the letters on the test chart determined?

Inasmuch as a visual angle of one minute is the smallest that can be perceived, the test letters are made of such size that the width of each line of the letter at its proper distance from the eye will form an angle of one minute, while the whole letter will form an angle of five minutes.

If a cylinder is placed before the emmetropic eye and two sets of lines are looked at, one agreeing with the axis of the cylinder and the other at right angles to this, will one set of lines be seen best?

Assuming the eye to be in a static condition, the lines agreeing with the axis of the cylinder will be more or less blurred according to the nature and strength of the cylinder, while the lines at right angles to this will be unimpaired because seen through the axis of the cylinder, which is plano, always bearing in mind the fact that vertical lines are seen by horizontal meridian of eye, and horizontal lines by vertical meridian of eye.

A pinhole disk is usually claimed as showing whether a refractive error is present or not. Under what condition would this not be correct?

If in a case of impaired vision the pinhole disk raised it to normal, we are justified in saying a refractive error is present. If, however, there was opacity of any refracting medium or atrophy of the optic nerve, there could be no improvement in vision on this account, and yet there might be an error of refraction in addition.

If an eye is 2 D. hypermetropic in the vertical meridian and you place a + 2 sphere in front of this eye, what is the condition thus artificially produced?

This + 2 D. sphere will correct the vertical hypermetropic meridian and make it emmetropic, but at the same time it will make the emmetropic horizontal meridian artificially myopic to the extent of 2 D.

Which set of lines in a cross-dial chart shows the axis of the astigmatism?

The horizontal lines are seen by the vertical meridian of the eye, and the vertical lines by the horizontal meridian of the eye. Therefore, if the horizontal lines are indistinct, the vertical meridian of the eye is assumed to be defective; and if the vertical lines are indistinct, we assume that the horizontal meridian of the eye is defective.

It must be further remembered that the meridian of the axis of a cylinder is plane and that the refractive power lies in the meridian at right angles thereto. Hence we place the axis at right angles to the defective meridian; and the indistinct lines are also at right angles to the defective meridian, and therefore the axis must be in the same meridian as the indistinct lines.

But suppose the defective meridian was hypermetropic and the accommodation came into action, as is likely to be the case; then the naturally ametropic meridian is made artificially emmetropic, and the naturally emmetropic meridian is made artificially ametropic, and under these circumstances the rule mentioned above will not apply at all as the axes are reversed.

For instance, in a case of simple hypermetropic astigmatism with the rule, the proper correcting lens is a + cyl. axis 90°; but if the accommodation is allowed to come into play, the lens accepted would be a − cyl. axis 180°.

Therefore, the use of the cross lines to determine the location for the axis of the cylinder is of value only when the accommodation is kept passive, as in the fogging method when it is repressed by a convex lens.

What is meant by exercise of the muscles or ocular gymnastics?

In cases of heterophoria, after the proper lenses have been given to correct the error of refraction, and perhaps the patient referred to his family physician to have his general health looked after, an effort may be made to strengthen the weak muscles by systematic exercise, to which the term "ocular gymnastics" has been applied.

The most promising cases are those of exophoria due to an insufficiency of the internal recti, which set of muscles we try to strengthen by exercise.

In the first exercise the patient is directed to take a pencil and hold it at arm's length in a perpendicular position. It should be held in the median line in front and gradually approached while the top of the pencil is fixed by the two eyes. When it gets to within a few inches from the eyes, the pencil is seen double, when it should at once be pushed off the starting point and the procedure done over again. This exercise can be kept up for five or ten minutes (if it does not nauseate the patient, as sometimes happens) and repeated daily.

The second exercise is by means of prisms placed over the eyes bases out, commencing with weak numbers and gradually increasing their strength while the patient looks at a point of light across the room. The strongest prisms are found which can be overcome and with which singleness of vision of the light can be maintained for a moment or two, and they will represent the present power of adduction.

Then the prisms are raised for a few seconds, and as they are lowered again diplopia is evident for an instant, but soon disappears. The prisms should be raised and lowered every thirty seconds for half a dozen times, when the prisms may be increased 2°. If his increase can be easily overcome, the prisms should be raised and lowered another half dozen times.

The idea to be kept in mind is to gradually increase the prisms about 2° at a time. The optometrist must use his judgment and not try to increase them too fast. This point can usually be determined by the readiness with which the temporary diplopia caused by dropping the prisms into place can be overcome. If the two lights run together as quick as a flash, then probably stronger prisms can be overcome and should be tried.

At the start, perhaps the eyes cannot overcome more than 6° or 8°, but as the muscles strengthen under the exercise and their innervation is stimulated, the prisms can be increased up to 40° or 50°. The exercises should be continued until this point is reached, because after they are stopped some of the adduction power thus developed must be expected to disappear.

What is the relation between prisms marked in degrees and prisms marked in prism diopters, and what is the relation between the value as marked on prisms and their deviating power?

In the case of prisms marked in degrees we say they are numbered by the refracting angle of the two surfaces of the glass where they meet at the edge or apex, founded on the fact that there are 360° in a circle and that 1/360th part of a circle would represent a prism of 1°.

In the case of prisms numbered in prism diopters the unit of this method of numbering is a prism diopter (which may be abbreviated P. D. or △) which will deviate a ray of light just 1 cm. at a distance of 1 meter, or 2 cm. for 2 meters, 3 cm. for 3 meters and so on in the same proportion for all distances, no matter what the index of refraction of the glass used may be.

A comparison of prisms marked in degrees with those numbered by prism diopters will show them to have nearly the same value; in fact, the difference is so slight that they can be used interchangeably in practice.

The relation between the number marked on the prism and its deviating power is as 2 to 1. That is, the angle of deviation is equal to about one-half the angle of the prism, which applies to all prisms of ten degrees or less. In prisms of a higher power the angle of deviation increases.

When prisms are ordered in a prescription how would you know that the prisms have been ground in the lens?

The first point to be looked for is a difference in thickness in the two opposite sides of the lens, comparing the inner and outer edges together, and the upper and lower.

Then we look to see if the lens shows the deviating effect of a prism by holding it in front of the eye at some little distance and viewing a straight edge or line across the room. If the prescrip-

tion calls for a lens of refractive power combined with the prism, we must be careful to look directly through the optical center of the lens, as otherwise the deviating power developed by looking through any refractive lens at a point away from its center will interfere with our efforts to detect the real prism in the combination. Perhaps the better way would be to first neutralize the refracting power of the lens and even here we must have a care to see that its optical center shall exactly coincide with the optical center of the neutralizing lens and then the presence of a prism becomes evident by a break in the line, no matter what part of the lens we look through.

Does decentering a sphere make a sphero-prism, or to make a sphero-prism must the sphere be on one side and the prism on the other?

The decentration of a sphere makes manifest its prismatic power, which then has the value of a sphero-prism, although it is only a spherical lens.

It would be impossible to have a prism on one surface of a lens, because a prism depends upon its two plane surfaces being inclined to each other, hence one surface of a lens could not show the effect of a prism. When a sphero-prism is ordered, a plane prism is taken and the desired spherical curvature is ground on one of its surfaces, the other surface remaining plane.

Upon what optical principle is the use of the Maddox rod based?

The Maddox rod produces very great magnification at right angles to its axis, elongating a small flame into a long streak of light. This result is such a great dissimilarity in the size, shape and appearance of the two retinal images that they cannot be fused into one, and as the eyes abandon the attempt to effect fusion, each eye is left to the action of its muscles and the eyes assume the position of unstrained equilibrium. Under these circumstances the position which the streak assumes with reference to the light will indicate either orthophoria or heterophoria.

Which position should be given to the prism placed on the Maddox rod before the normal right eye so as to deflect the observed

vertical line of light 12 cm. to the left at 6 meters distance? What is the power of the prism?

The displacement of objects viewed through a prism is always in the direction of the apex; therefore, in this case where it is desired to move the right image inwards or to the left, the prism would have to be placed base out over right eye.

Inasmuch as a prism diopter causes a deviation in a ray of light in the ratio of 1 cm. for each meter of distance, there will be a deviation of 3 cm. for 3 meters and 6 cm. for 6 meters. In this case where the deviation is 12 cm. for 6 meters, the power of the prism would be 2△.

In which position must the prism bases be placed to ascertain the powers of adduction, abduction, supraduction and infraduction, respectively?

Adduction, bases out.
Abduction, bases in.
Supraduction, bases down.
Infraduction, bases up.

Would you always prescribe glasses where ametropia is found to exist? If not, state exceptions.

No; in slight degrees of defect, where vision was but little if any impaired, and where there were no symptoms complained of, glasses would scarcely be justified; especially if slight hypermetropia existed with exophoria, or low myopia with esophoria.

With the Maddox rod horizontal before the left eye, the point of light being at six meters and the streak appearing 12 cm. to the right of the point, what is the kind and amount of heterophoria and in which direction would you place the base of a prism to bring the streak through the point of light?

As the diplopia in this case is crossed the condition is one of exophoria.

The deviation of one prism diopter is 1 cm. for each meter of distance, which would mean 6 cm. for 6m. Therefore, a displacement of 12 cm. would indicate 2△ of exophoria.

The base of prism is placed in to bring the streak through the light.

A plus 4 diopter lens is the correction called for in a case of hypermetropia. What is the effect of wearing this lens too far from the eye, say an inch, as, for instance, where the spectacles are pushed far down on the nose?

The effect of pushing the lens forward is to increase its strength. Therefore if + 4 D. is the proper correction in the usual position, it would be too strong when worn far down the nose.

If rays of light from a distance of 20 inches are focused on the retina with a plus 2 D. lens without accommodation, what is the refractive error?

Rays of light diverging from a distance of 20 inches and passing through a convex lens of 2 D. would emerge parallel, and if such rays were focused on the retina without accommodation, the eye must be emmetropic.

What is the ametropic correction for a patient, age twenty years, with his near point of the vertical meridian at 8 inches and the near point of the horizontal meridian at 10 inches?

The emmetropic eye at 20 years of age possesses 10 D. amplitude of accommodation in both meridians.

In this case a near point of 8 inches in the vertical meridian shows 5 D. of accommodation for this meridian, which is a deficiency of 5 D. and a probable hypermetropia of this amount. In the horizontal meridian the near point of 10 inches shows 4 D. of accommodation on a deficiency of 6 D. and a probable hypermetropia of this amount. This would be compound hypermetropic astigmatism and the correction reads as follows:

+ 5 D. sph. ⊃ + 1 D. cyl. axis 90°

What is the correct prescription for distance, for a patient aged thirty years, looking at 13 inches with his focus on the retina, while wearing a + 2 sphere on a − 3 cyl. axis 90°, using 2 D. of accommodation?

An emmetropic eye looking at 13 inches uses 3 D. of accommodation. If, however, in this case a + 2 D. sphere is worn and in addition it is necessary to use 2 D. of accommodation, then this 4 D. would indicate that 1 D. more than in emmetropia is necessary, revealing a hypermetropia of this amount; therefore the correct prescription for distance would be

+ 1 D. sph. ⊃ − 3 D. cyl. axis 90°

A patient is told to look at a small light 20 feet away and is given diplopia with a prism, base down, before the right eye. What defect and amount of error are present when the upper light is located to the right, and a prism of 3° before each eye is required to bring both lights to the median line? What is the position of the 3° prisms?

If the prism is base down before right eye then the right image belongs to right eye and the condition is one of esophoria. The correcting prisms of 3° must be placed bases *out* to bring the lights one under the other.

A myope of 3 D. sees with his right eye the Maddox rod line 9 cm. lower than the object light. Write the prescription for distance lenses, lenses to be O eye, so that the least cost will be incurred.

The deviation caused by one prism diopter is 1 cm. for each meter distance. Presuming this test was made at the usual distance of 6 meters, the deviation would equal 6 cm. The question says there is a deviation of 9 cm., which, figured out on the above basis, would correspond to 1½ prism D.

The amount of prismatic power that can be developed by decentration is on the basis of 1 △ for every 1 D. when decentered 10 mm., or ½ △ for every 1 D. when decentered 5 mm., or 1½ △ for this 3 D. lens when decentered 5 mm.

The rough lens would not be large enough to permit of this decentration in the horizontal meridian, but it can be done in the vertical meridian, which is 9 mm. less than the horizontal.

As the right eye image is lower than the left the case is one of right hyperphoria, which is to be corrected by prism base down right eye, or base up left eye.

As this is a concave lens the base of prism is opposite to the direction of decentration, as the preferable direction for base of prism is up, as it is customary to place the prism over the left eye (unless the right eye is decidedly the poorer eye), and as it is desired to avoid prisms in order to incur the least cost, we will order

O. D. − 3 D. sph.
O. S. − 3 D. sph. decentered down 5 mm.

What are the points of resemblance and difference between a case of spasm of the accommodation and a case of myopia? In what kind and what degree of ametropia does spasm of the accommodation generally occur?

The points of resemblance are that in both conditions the reading point is closer than normal, and the acuteness of vision is impaired, which is improved by concave lenses.

The points of difference are:

(1) In spasm the distance of the far point does not correspond to the degree of defect as it does in myopia.

(2) In spasm the visual acuity is constantly varying, while in myopia it is more likely to be a fixed quantity either with the naked eye or with the correcting lenses.

(3) In spasm there are complaints of pain and inability to use the eyes continuously for near work, while in myopia there are no asthenopic symptoms.

(4) In spasm the near point is apt to be closer to the eyes for a given degree of false myopia than for a similar degree of real myopia.

(5) In spasm the distant vision is better than the near, while in myopia the near vision is better than the distant.

What is presbyopia due to and how does it differ from acquired hypermetropia?

Presbyopia is due to an inability to accommodate sufficiently to make near vision clear, on account of the sclerosis of the crystalline lens which comes on with age and becomes noticeable in the early 40's only when near vision is attempted.

As the presbyopic changes progress there comes a time late in life when distant vision also becomes impaired as a result of the lessened refractive power of the crystalline and then convex lenses are needed not only for reading but also for distance, the latter being weaker than the former. This condition is known as acquired hypermetropia.

What is meant by mixed astigmatism? Describe the best method of testing such a case and what directions you would give as to the wearing of glasses.

Mixed astigmatism is that condition in which the focal line of one meridian lies in front of the retina and of the other meridian back of the retina; or in other words, one meridian is myopic and the other hypermetropic.

The best method of subjective testing is (after having used the ophthalmometer and determining the presence of astigmatism and the location of the principal meridians) to correct the hypermetropic meridian by means of convex cylinders, which should be crowded on to the limit of acceptance and which will not affect the other meridian, and then use concave cylinders over the convex cylinder with their axes at right angles. The convex cylinder will advance the focus of the hypermetropic meridian to the retina, and the concave cylinder will throw the focus of the myopic meridian back to the retina, so that the image will now be composed of focal points on the retina instead of focal lines in front and back of it.

The cross cylinder thus obtained can usually with advantage be transposed into a sphero-cylinder, in which case it is sometimes desirable to slightly reduce the convex element of the combination in order to make them more acceptable to the patient.

The same principle can be used in the retinoscopic test. After having determined the directions of the two principal meridians the hypermetropic is neutralized by a convex sphere and the myopic meridian by a concave sphere, from which, after making the necessary allowances, the correcting combination can be de-

duced, remembering that the axis must be placed at right angles to the meridian.

In mixed astigmatism the glasses should be worn constantly and care should be taken that the glasses are kept in proper adjustment and without displacement of the axes, which in the higher degrees of mixed astigmatism would result in impairment of vision and asthenopic symptoms.

If a patient has myopic astigmatism, in what case would plus cylinder be prescribed?

In a case of simple myopic astigmatism, convex cylinders could not be prescribed unless combined with the same number concave sphere, but this would increase the cost.

In compound myopic astigmatism the transposition may be made in order to get a higher concave surface and thus make a periscopic effect, or to change the axis from horizontal to vertical, or for both purposes.

For instance:

$$-\ 3\ \text{D. sph.} \bigcirc -\ 2\ \text{D. cyl. axis } 180^\circ$$

may be transposed to

$$-\ 5\ \text{D. sph.} \bigcirc +\ 2\ \text{D. cyl. axis } 90^\circ,$$

with the gain of both of the above-mentioned advantages.

If a person requires plus 5 D. in the vertical meridian and plus 4 D. in the horizontal and is tested with a small astigmatic clock dial, what would be the farthest distance at which the vertical line could be distinctly seen; also the horizontal lines, with a plus 8 D. lens?

If the vertical meridian is hypermetropic to the extent of 5 D. and a + 8 D. lens is placed before it, there is an overcorrection of 3 D., thus producing an artificial myopia of like amount, with a far point for this meridian of 13 inches. And as the horizontal lines are seen by the vertical meridian of the eye, therefore, 13 inches would be the farthest distance at which the horizontal lines could be distinctly seen.

If the horizontal meridian is hypermetropic 4 D., and a + 8 D. lens is placed before it, there is an overcorrection of 4 D. with

an artificial myopia of like amount and a far point of 10 inches. And as the vertical lines are seen by the horizontal meridian 10 inches would be the farthest point at which the vertical lines could be seen.

What change in adjustment must be made when a myope looks through a pair of field glasses just used by an emmetrope?

The tube must be shortened in order to make the emergent rays divergent and thus be able to focus on the retina of the myopic eye.

What is the prismatic effect in a pair of glasses set in a frame 5 mm. too wide when the prescription is as follows:

R. E. + 2.50 ○ − 1 cyl. axis 90
L. E. + 3.50 ○ − 1.50 cyl. axis 90

The prismatic effect is produced by a decentration in the horizontal meridian, the power of which is reduced in both lenses by the concave cylinders to 1.50 D. in right and 2 D. in left eye.

The rule is $1\triangle$ of prismatic power for every diopter when decentered 10 mm. In this case where the frame is 5 mm. too wide there is 2.5 mm. decentration for each eye, which according to the above rule would yield $\frac{3}{8}\triangle$ for right eye and $\frac{1}{2}\triangle$ for left eye, or a total for the two eyes of $\frac{7}{8}\triangle$ of prismatic effect.

The following is a prescription in which the correction for the right eye is omitted. Supply it:

Distance R. E. − 0.50 − 1.00 cyl. axis 45°.
Distance L. E. missing.
Near R. E. + 0.50 ○ + 1.00 cyl. axis 135.
Near L. E. + 3.50 ○ − 0.75 cyl. axis 135.

A comparison of the distance and near corrections of the right eye shows the addition of a + 2 D. and a transposition of the cylinder from concave to convex.

Assuming that the same addition was made in the near glass of the left eye, we must deduct this 2 D., which would leave

+ 1.50 D. S. − .75 D. cyl. axis 135°

or by transposition in order to correspond with right eye

+ .75 D. S. + .75 D. cyl. axis 45°

What advantage is secured by using the Maddox rod test as a phorometric test?

The principal advantage of the Maddox rod is that its image, although distorted and elongated into a streak, is formed upon the macula; whereas in the prism test the images are displaced from the macula.

What errors of refraction may be congenital and which ones acquired?

Usually we regard hypermetropic errors as congenital and myopic as acquired.

What is asthenopia?

The word means weak sight and is used in connection with a condition where the eyes can be used but for a short time, and is accompanied by more or less discomfort, due to strain of either the accommodation or convergence.

Describe a test of the extrinsic muscles which is dynamic; that is, the test must be made with convergence in full action.

Ask the person being examined to look at the point of a pencil which is held in the median line a short distance in front of the face and gradually moved nearer to the eyes until one of them is seen to abandon the effort of convergence and deviate from the fixation point and turn outward. The position of the pencil when this occurs indicates the near point of convergence. This has been estimated to be normally about four inches from eyes.

Describe a test of the extrinsic muscles of the eyes that is not dynamic; that is, the test is not made with convergence in full force.

Any test that is made with a distant point of fixation, as for instance the Maddox rod test with the light 20 feet away. This is a test that is "not dynamic" because there is no impulse to the convergence for the maintenance of binocular vision.

In an astigmatic eye where would be the circle of least diffusion?

In astigmatism the two principal meridians each have a different focus, the space between which is known as the focal interval of Sturm. No matter what the position of the retina in such an eye, no distinct image can be formed upon it.

If it is in focus for one meridian it is very much out of focus for the other. The accommodation is brought into action to lessen as much as possible the diffusion circles, but there can be no true focus for both meridians at the same time, and therefore the image cannot be sharp and distinct. Probably the best vision or least diffusion would be midway between the foci of the two meridians.

Why are prisms placed bases in and out, respectively, in convergent and divergent strabismus?

Ordinarily, strabismus is beyond the reach of prisms, but if correctible by prisms the rule is to place the base opposite to deviation, that is, in convergent strabismus, base out, and in divergent strabismus, base in. These are the positions of relief and assistance.

But if it is desired to develop and strengthen a set of muscles by prism exercise, then the apex of the prism is placed over the muscles which it is desired to act upon, that is, in the positions named in the question. In convergent strabismus, where it is desired to exercise the external recti, the prism is placed apex out or base in; in divergent strabismus, where the internal recti need toning up, the prism is placed apex in or base out.

In a young person with 1 diopter of hyperopia the pinhole disk makes the letters on the chart worse than when seen with the naked eye, while in a myope of 1 diopter there will be an improvement with this test. What is the reason?

The pinhole test is one that is of value only when vision is impaired. In the case of a young person with 1 D. of hypermetropia the visual acuity is not lessened because the accommodation instinctively neutralizes the deficient refraction. As the vision is already normal the pinhole disk cannot make it

any better, but rather makes it worse because it cuts off so much light that would otherwise enter the eye.

Whereas, in the case of a myope of 1 D. the acuteness of vision is much impaired (probably one-half normal), but it is at once raised to normal by the pinhole disk, for the following reason:

The pinhole allows the passage of a very narrow pencil of light and to that extent diminishes the size of the diffusion circles on the retina. If the pinhole be 1/5 the size of the pupil, the diffusion circle on the retina will be only 1/5 the size of the usual diffusion circle.

Suppose the diffusion circle upon the retina covered an area of 100 cones; with a pinhole 1/5 the diameter of the pupil the area will be reduced 1/25, and only 4 cones be covered; this will result in an enormous increase in the visual acuity.

In a case of hypermetropia of 6 diopters with little accommodation how would we measure the amount of facultative hypermetropia?

By the proportion of the total hypermetropia that can be overcome by the accommodation. If this case of 6 D. of hypermetropia was fifty years of age he would possess about 2.50 D. of accommodation, which would be used as far as it would go in the correction of the defect, and the balance must be corrected by lenses.

In this case there would be 2.50 D. of facultative and 3.50 D. of absolute hypermetropia. The facultative is the difference between the total defect and the weakest lens that raises vision to normal.

How would you get the amplitude of the convergence-accommodative function?

By measuring the closest point at which it is possible to see clearly and at the same time that binocular vision can be maintained. The accommodation is expressed in diopters and the convergence in meter angles.

In the emmetropic eye an object situated at 8 inches would call for 5 D. of accommodation and 5 meter angles of convergence.

In what way can eye with irregular astigmatism be best corrected?

The center of the cornea may be flatter or more convex, thus giving it a different refractive power from the periphery; or the cornea may be studded with numerous facets, the results of previous ulcers; in either case vision is impaired and objects distorted.

It is obvious that such a condition is not correctible by the usual forms of lenses. The only method of improving vision is to cut off the peripheral rays and allow light to pass through a small portion of the cornea, where the curvature is most even and the transparency greatest. This can be accomplished by an opaque diaphragm with a small opening placed before the cornea in the position that is found the most favorable.

The distance correction is
O. D. + 2 D. sph. *O. S. − 1 D. sph.*
What decentration must be given to the added wafers of + 2.50 D. for reading in order to neutralize the prismatic effects which would otherwise be produced by looking through the centers of the lower fields, 10 mm. below the centers of the distance lenses?

On account of the size of the finished lenses it would be utterly impossible to obtain a decentration of 10 mm.; with this proviso we will answer the question as it is given.

The decentration for the two wafers will not be the same because the distance lenses vary in character and in power.

According to the rule which has already been given on these pages, the prism strength that would be developed by a down decentration of 10 mm. of this convex lens of 2 D. would be 2° with base *up*. Therefore, in order to overcome this the wafer on this lens would have to be decentered down to a corresponding degree, but as the power of this wafer is 2.50 D. the decentration necessary to produce a 2° prismatic value base down to balance would be only 8 mm.

In regard to the left lens, which is a concave lens of 1 D. power the decentration downward of 10 mm. would produce a prism value of 1°, but in this case with base *down*. In order to

counterbalance this the decentration of the + 2.50 D. wafer would have to be *up* to the extent of 4 mm.

In a case of this kind it would be well also to order the segments decentered inwards, or rather order the pupillary distance of the segments to less than that of the distance lenses, to allow for the necessary convergence and decrease of pupillary distance when the eyes are used at close range.

The wearer of a pair of strong minus lenses complains that distant objects appear clear but diminished in size; how may this defect be rectified in part at least without altering the power of the lenses?

By pushing the glasses as close to the eyes as possible.

Describe an accurate subjective method for detecting astigmia and determining its character.

Astigmatism may be detected subjectively in two ways:

1. Use of the card of radiating lines, and the reply of the patient that lines running in one direction are notably plainer and more distinct than lines running in some other directions.
2. Use of the card of test letters and the acceptance by the patient of the cylinder as affording better vision than a sphere.

The character of the astigmatism is determined in each case by the lenses required. If convex are accepted, hypermetropic; if concave are required, myopic.

A child in good health shows under objective test by the static method 5 D. of hyperopia and with the Maddox rod test or a similar test esophoria of 8 degrees, what correction would you prescribe?

The fact that hypermetropia and esophoria exist together shows that the functions of accommodation and convergence maintain their proper relation to each other. Under such circumstances we are usually justified in giving the full correction for the refractive error. Whether or not we would prescribe exactly the + 5 D. would depend upon the age of the patient and the effect of the lenses on the acuteness of vision. If the child was over 6 and the acuteness of vision was markedly diminished by the

lenses, we might feel it advisable to reduce them, whereas younger children bear stronger lenses and possible blurring with little complaint.

Explain the uses of the stenopaic slit and the pinhole disk and give the practical value of each.

The stenopaic slit is intended to restrict the rays of light entering the eye to one meridian and in this way we can study the acuteness of vision and refraction of that one particular meridian. When placed at 90 degrees the vertical meridian comes under observation; when at 180 degrees, the horizontal. Its special field is in the detection and correction of astigmatism.

The stenopaic slit is placed in the Trial Frame and rotated through the different meridians, while the patient looks at the letters on the test card. In this way each meridian for the moment performs the act of vision, and if there is any difference in vision in the various meridians, getting better in one way and getting worse in the other, astigmatism is shown to be present. For instance, when at 90 degrees vision may be 20/20 and at 180 degrees, 20/30. The spherical lens placed in front of the slit will measure the refraction of each meridian, and the difference between the two lenses will show the amount of astigmatism.

The pinhole disk is made use of in cases of greatly impaired vision to determine if the trouble is due to an error of refraction or not. If the pinhole raises vision, then glasses will be of benefit; but if it fails to cause any improvement then there is little use to try to prescribe glasses. This is a simple and practical method to determine if the impaired vision is due to disease or to refractive error.

How may it be positively determined (subjectively) whether or not ametropia is present when vision is 20/20 without lenses? What may be the character of the ametropia?

It is possible for vision to equal 20/20 in presence of hypermetropia or slight hypermetropic astigmatism because the accommodation is instinctively brought into action to overcome the deficient refraction and maintain vision at the normal standard. In such cases weak convex lenses may be accepted, but just as

often they are rejected; the proper way to positively determine the presence of hypermetropia, which may be latent, is by means of the fogging system.

A patient 35 years of age having 3 diopters of hypermetropia asks for "reading" glasses but complains of constant migraine; give the correction that you would order and state, with reason, when in your opinion the glasses should be worn.

The fact that the patient suffers with constant headache would be sufficient reason for advising glasses to be worn constantly. We do not know what method was used to measure the 3 D. of hypermetropia, nor what the acuteness of vision was naturally and with glasses. Perhaps the patient will not bear the full correction for constant wear, in which case we would order as strong as can be comfortably worn for that purpose, and the + 3 D. as an additional pair for reading. As patient will probably object to two pairs of glasses, we would theoretically be justified in ordering the + 3 D. for constant wear and also for reading, but in practice we are sometimes compelled to modify as above.

If there is a tendency of the eyes to cross, on which side will the light streak appear with the Maddox rod over the left eye? How should the prism be placed to bring the lights together?

By "tendency of the eyes to cross" we understand a tendency to convergent strabismus; this would result in homonymous diplopia, in which right image belongs to right eye and left image to left eye.

With Maddox rod over left eye, the streak of light would appear to the left; this is corrected by prism placed base out, because prisms displace objects toward their apex.

State (a) how the amplitude of accommodation is measured, (b) how convergence is measured.

(a) The nearest point for which the eye can accommodate by the strongest effort of the ciliary muscle represents the amplitude of accommodation. As explained above, if this should

be 5 inches, then 8 D. is the measure of the amplitude of accommodation; if at 4 inches, then 10 D. of accommodation.

(b) The degree of convergence is measured by the angle through which each eye must turn from parallelism of the visual lines in order to converge to the near point of fixation. The amplitude of convergence is the distance from the far point to the near point of convergence, and is expressed by the greatest number of meter angles which the eyes can exert, the meter angle being that angle through which the eyes must turn from parallelism to converge at a point one meter away. At 20 inches (½ meter) there would be 2 meter angles of convergence; at 10 (¼ meter) 4 meter angles, and so on. In emmetropia the convergence and accommodation are equal; for instance, at 10 inches there are 4 meter angles of convergence and 4 D. of accommodation.

The convergence can also be measured by the strongest prisms, bases out, which the eyes are able to overcome and maintain single vision.

Give reasons for and against full correction of myopia (a) in orthophoria, (b) in heterophoria.

(*a*) When orthoporia exists in connection with myopia, the indications would be against the full correction of the refractive error, all other things being equal, because the normal relation between accommodation and convergence has not been maintained.

(*b*) If esophoria exists in connection with myopia, the indications are still stronger against the full correction of the refractive error, because the relations between it and the muscle balance are just the reverse of what they should be.

When exophoria exists in connection with myopia, full correction of the latter is indicated, because the relations are normal, and the concave lens also corrects the tendency to outward deviation.

If an addition to the prescription for distance glasses must be made for presbyopia of + 3.50 D. or more, what error in the prescription for distance should be suspected?

For the correction of simple and uncomplicated presbyopia, glasses are seldom required stronger than + 3 D. Therefore, in

the case mentioned where + 3.50 D. or more must be added for reading, it is fair to assume that the hypermetropia has not been fully corrected and that the distance glasses are not as strong as they should be.

State (not describe) the various methods you would employ in making a thorough examination of the eyes. Write a hypothetic prescription involving sphero-cylinder prisms in bifocal form and give a complete case record of the same.

Acuteness of vision.
Amplitude of accommodation.
Ophthalmometer.
Ophthalmoscope.
Retinoscope.
Trial case examination.
Muscle tests.
O. D. = 20/60 − 1 D. sph. − 50 D. cyl. axis 180° = 20/20.
O. S. = 20/40 − 50 D. sph. − 50 D. cyl. axis 180° = 20/20.
Reads .50 D. type, 10″ to 30″.
Ophthalmometer shows .50 D. excess in vertical meridian.
Ophthalmoscope, normal fundus.
Retinoscope, against movement.
R. E., − 1 horizontally, − 1.50 vertically.
L. E., − .50 horizontally, − 1 vertically.
Maddox rod = 4° exophoria.
Prescription given as follows:
O. D., − 1 D. sph. − .50 D. cyl. axis 180° ⊃ Pr. 1° b. in.
O. S., − .50 D. sph. − .50 D. cyl. axis 180° ⊃ Pr. 1° b. in.
+ 1.50 D. segments added.

After fogging the vision with plus lenses how do you proceed and when do you stop?

Proceed to neutralize the excessive convexity and reduce the fogging by means of concave lenses placed in front of the fogging lens and gradually increased until a vision of 20/20 is reached. We must stop here or the purpose of the fogging system would be

defeated. Stronger concaves would be accepted if used but they must not be tried.

About how much difference can be made in glasses when the eyes are not alike in focus?

If a rule must be given we would say from 1.50 D. to 2 D., but there is a wide difference of opinion on this point. The writer has had cases where a difference of 4 D. and 5 D. has been made. After all it is a matter that must be left to experience in each individual case. The effort should always be made to give each eye its own proper correction. If such a difference proves uncomfortable then the glass of the poorer eye must be changed but only so much as to make it bearable.

Do you prescribe the weakest or strongest lens with which a patient can see 20/20 in hypermetropia and why?

We give preference to the stronger glass in order to relieve the unnatural tax upon the accommodation and because the strongest convex lens is the measure of the manifest hypermetropia only and there is usually some latent error back of it which is not discovered by any lens.

In myopia? Why?

In myopia we give preference to the weakest glass in order to lessen the tax upon the accommodation and because there is usually some spasm of the ciliary muscle, which makes the myopia appear greater than it actually is and thus leads to the choice of a concave glass that is stronger than enough to correct the real amount of myopia.

What is presbyopia and how corrected?

Presbyopia is that condition of vision where on account of a failure of accommodation, due to a loss of contractility of the ciliary muscle and of elasticity of the crystalline lens, the near point recedes to an inconvenient distance and reading is impaired or made impossible.

It is corrected by means of a convex lens, which restores the receded near point, assists the accommodation and places in front of the eye the necessary convexity which has been lost within it.

How do you test the external and internal muscles?

By prisms, with apex over the muscle it is desired to test.

How many degrees of prism, base out, should a person overcome?

20° to 30°.

How many degrees of prism should a person overcome base in? Up or down?

6° to 8° base in.
2° to 3° up or down.

If the eyes turn in, how do you place the base of a prism?

Out, the rule being base opposite to deviation.

What is the object of fogging with strong plus lenses?

To encourage relaxation of the ciliary muscle and reduce spasm of the accommodation.

How do you test for astigmatism?

Objectively by the ophthalmometer and the retinoscope and subjectively by the radiating lines and cylindrical lenses.

How would you use the stenopaic slit in finding the error of refraction in an eye which has astigmatism?

The stenopaic slit is placed in position before the eye of the patient, who is asked to look at the test letters. It is then rotated to that place where the letters are seen the plainest, which will be one of the principal meridians and that of best vision.

The meridian at right angles will be the other principal meridian and that of poorest vision. The refraction of each meridian is measured by spherical lenses.

If the vision in the first meridian is normal, this meridian may be emmetropic or hypermetropic. The vision in the second meridian is necessarily below normal, and may be hypermetropic or myopic.

Convex lenses are tried in the first meridian; if rejected we assume this meridian is normal and the case one of simple astigmatism. If accepted, this meridian is hypermetropic and the astigmatism is either compound or mixed.

The second meridian is measured by convex and concave lenses in the usual way. If convex lenses (of different strengths) are accepted in both meridians, the astigmatism is compound; if convex lenses in one meridian and concave in the other, mixed.

It must be remembered that the axis of the correcting cylinder is to be placed at right angles to the meridian that is being measured. For instance, if + .50 D. is accepted in the vertical meridian, the correcting lens would be + .50 D. cyl. axis 180°.

If + 1 D. is accepted in the horizontal meridian, the correcting lens would be + 1 D. cyl. axis 90°.

And the prescription would be + .50 D. sph. $\bigcirc$ + .50 D. cyl. axis 90°.

What is understood by the so-called "cover" and "fixation" tests for muscular weaknesses?

In any case of muscular weakness we assume the good eye to be the fixing eye. The patient is asked to look at an object some distance, a light being the best. A card is then placed over the fixing eye, thus excluding it from vision, when the patient will be compelled to use his other eye to see the light. If this causes any movement in either eye there is evidence of muscular insufficiency. Both eyes should be covered in turn, and if there is no movement of either eye after covering or uncovering, both eyes would seem to fix, thus contraindicating insufficiency.

If either eye turns inward when its fellow is covered, it must previously have been deviating outwards; and if the excursion should be outward, the previous deviation must have been inward.

In the fixation test both eyes look at an object, the distance of which is quickly changed, while the corresponding movements of the two eyes are closely watched, according to which we can detect the presence of insufficiency.

What test may be applied to determine whether or not an anisometrope will accept his full correction for widely different states of refraction?

There is no definite test at our command by which we can determine this point. It is a matter that really can be decided only by the experience of the patient. The glasses should be tried for ten or fifteen minutes in the office, and if there is no decided objection they may be given tentatively for a few days' or a few weeks' wear. If there is a slight discomfort at first, this may pass away after a few days wearing of the glasses. At any rate a reasonable effort must be made to have the eyes bear the full correction for each eye.

What do you consider the most satisfactory way of correcting high myopia; full correction or partial correction?

This depends upon a great many circumstances, such as age, amplitude of accommodation, whether glasses had been previously worn, and if so, the proportion of full correction and the character of the work for which the eyes are to be used, as well as the degree of defect and the amount of vision obtainable.

When patient first puts on glasses it is best to start with an undercorrection, which may be increased from time to time until the full correction is reached for distance. But for close use glasses 2 D. to 3 D. weaker should be used.

It is understood that the stronger the concave lenses the greater the tax upon the accommodation, and as this function is less developed in myopia, caution must be observed not to increase this tax to the point of causing asthenopia. On the other hand, it may be possible to contribute to the ciliary insufficiency by weak lenses, or to develop the strength of the accommodation by lenses that are purposely made stronger for that purpose.

Name and describe the two principal divisions of hypermetropia.

Hypermetropia as met with may be divided into manifest and latent. Manifest is that which is not concealed by the ciliary muscle, and is determined by the strongest glass the patient can be induced to accept for distant vision. Latent hypermetropia is that which is neutralized by the power of accommodation, and usually in its entirety can be revealed only by the action of a cycloplegic.

The manifest error may vary from time to time according to the tonicity of the ciliary muscle. In youth the manifest is proportionately small and the latent correspondingly large. With the advance of years the manifest increases at the expense of the latent, until finally the defect is all manifest. This condition is then known as absolute hypermetropia, when vision becomes impaired and convex lenses are a necessity.

Explain the states of vision that should govern the decision as to whether or not lenses should be worn constantly.

Theoretically, all errors of refraction call for constant wearing of glasses, but this is particularly true of hypermetropia and hypermetropic astigmatism; and yet even here in slight degrees of defect in the presence of a vigorous accommodation there may be exceptions to this rule. In mild cases of myopia where the distant vision is not inconveniently impaired, the constant wearing of glasses may be considered as much a luxury as a necessity.

Independent of the condition of vision, and even when vision is normal, there are many cases that require the constant wearing of glasses to relieve the strain.

Describe the methods of measuring the amplitudes of accommodation and convergence.

In order to measure the amplitude of accommodation the patient is given a card of very fine print and the very closest point at which it is possible to read this is measured in inches;

this is transposed into diopters, which will represent the amplitude of accommodation.

To measure the amplitude of convergence a pin may be used and the closest possible point at which it is seen singly will be noted, and this corrected into meter angles.

What error of refraction is often indicated on the surface of the cornea?

Astigmatism.

What is the condition called if the right eye deviates upward?

Right hyperphoria, or if there is actual and noticeable deviation, right hypertropia.

Name four methods of detecting hyperphoria.

Maddox rod, Maddox double prism, phorometer and prism test.

What advice would you give to a patient when he first wears glasses?

This depends somewhat on the character and degree of the refractive error. In hypermetropia and astigmatism we would tell him the glasses may seem strange at first and that it will take him a little time to get accustomed to them. We will warn him that the ground may seem to slant as if he were walking up hill and there may be some distortion of objects, but that if he will persist in wearing the glasses for several days these unpleasantnesses will most likely gradually pass away. In many of these cases the natural acuteness of vision is normal, hence in order that a patient may not be disappointed it is well to tell him that the glasses are not intended to make him see better, but to relieve the strain and discomfort from which he suffers.

In making a rapid preliminary examination what would cause you to suspect high myopia?

A great impairment of distant vision, so that even the largest letters on the test card could not be named; a tendency to bring reading and small objects very close to the eyes, and a squinting or half closing of the lids; a dull, slow movement against the mirror with the plane retinoscope; a rejection of convex lenses and a marked improvement in vision by concave lenses.

When will a hyperope accept minus glasses for distance?

When there is spasm of accommodation, as there usually is in hypermetropia. If the accommodation was passive rays of light would strike the retina before they could come to a focus, resulting in a blurred image; but as soon as the eyes are opened the accommodation at once comes into action to increase the refractive power of the hypermetropic eye and bring the rays to a focus on the retina. It sometimes happens that this action of the accommodation is overdone; that is, more effort is exerted than is just necessary to neutralize the hypermetropia, and then a condition of false myopia is produced when concave lenses would be accepted. It goes without saying that even if accepted, concave lenses should not be prescribed in hypermetropia.

What is astigmatism?

That condition of the eye where its refraction is similar to a sphero-cylindrical lens, where there are two meridians of greatest and least curvature, the difference between which represents the amount of astigmatism, and as a result the rays cannot be focussed at a single point, but there is a focus for each meridian.

In the practice of optometry what is sought to be done by the use of lenses?

To correct ametropia and heterophoria. To add to the refractive power where deficient, as in hypermetropia; to lessen the refractive power where excessive, as in myopia, and to equalize the refraction in all the meridians of the eye, when one or more are in error, as in astigmatism. In other words, to make the eyes emmetropic. In heterophoria to assist the deficient

muscles by prisms in position of relief and thus restore the proper equilibrium; also to develop these muscles by prisms in position of exercise. To neutralize any deficiency in accommodation, as in presbyopia. In fine, to improve vision or make it more comfortable by removing strain.

In testing with the stenopaic slit it is found that the right eye requires + 1.75 in the vertical meridian and − .75 in the horizontal. What is the prescription?

+ 1.75 D. cyl. ax. 180° ⊂⊃ − .75 D. cyl. ax. 90°

This cross cylinder may be transposed into either of the following sphero-cylinders:

+ 1.75 D. sph. ⊂⊃ − 2.50 D. cyl. axis 90°
− .75 D. sph. ⊂⊃ + 2.50 D. cyl. axis 180°

What rule is to be observed in the giving of minus lenses in myopia?

When a concave lens of the proper strength to exactly neutralize the myopia is placed before such an eye, parallel rays are diverged just enough to throw the focus from in front of the retina back on to the retina. If the concave lens is any stronger than necessary the rays are made more divergent, which would tend to cause them to focus behind the retina; but the accommodation instinctively comes into action to bring the focus of these divergent rays forward to the retina. This led to the rule that in myopia the weakest glasses that afford satisfactory vision should be prescribed in order to avoid a tax upon the accommodation.

It may be argued that a hypermetrope sees better with a glass that is not a full correction and which allows him to use some of his accommodation, and hence there is no harm in an over-correction of myopia where vision is made perfectly clear by a slight use of the accommodation. But it must be remembered that the former is accustomed to accommodating and his ciliary muscle is large and well developed, while in the latter case there is but little need for accommodation and the ciliary muscle is small and weak. Of course, if glasses are placed in

youth on a patient who is vigorous the ciliary muscle is likely to develop the normal power, but if glasses are first worn later in life, or in any case as age creeps on, the glasses should be kept weak, or reduced for close use.

What is indicated when the pinhole disk alone produces marked improvement of vision?

That the impairment of vision is due to an error of refraction and that it can be corrected by lenses.

The patient is directed to look at a light 20 feet distant and is given diplopia with a prism, base down, before the right eye; what defect and amount of error are present when the upper light is located to the left and a prism of 5° before each eye is required to bring both lights to the median line? What is the position of the 5° prisms?

An artificial vertical diplopia is produced by the prism base down before right eye. The upper light will belong to this eye, and if it is located to the left a condition of crossed diplopia is shown to be present, due to an exophoria. The amount of the imbalance is 10° and the prisms are placed bases in.

A hyperope of 2.5 D. sees with his right eye the Maddox-rod line 6 cm. higher than the object light; write the prescription for distance lenses, O eye size, so that the least cost will be incurred.

Inasmuch as the image formed in the right eye is the highest, the condition is one of left hyperphoria, which can be corrected by prism base down left eye or base up right eye. And as it is desired to write a prescription incurring the least cost, it is necessary to obtain this prismatic effect by a decentering of the lenses.

No mention is made of the distance at which the test is made, but we will assume the usual distance of 20 feet or 6 meters. The deviation for one prism diopter is just 1 cm. for each meter of distance; hence for 6 meters there is 6 cm. of displacement. Therefore, in this instance where there is 6 cm. of deviation, there is indicated 1 p. d. of insufficiency.

The rule for decentration is as many degrees of prism power as there are diopters of refractive power for every decentration of 10 mm. In this case the combined value of the two lenses is 5 D., which would afford 5° of prismatic power if decentered 10 mm., or 1° prismatic power if decentered 2 mm. As this is the amount desired, it can be obtained by decentering the right lens, 2 mm. up, or the left lens 2 mm. down, or dividing the decentration between the two eyes, right eye 1 mm. up and left eye 1 mm. down.

What are the conditions of vision which make the use of distance glasses imperative?

When the acuteness of vision is so greatly impaired by marked degrees of myopia, hypermetropia or astigmatism as to interfere with the ordinary occupations of life, or to make walking in a crowded street difficult or dangerous.

When may distance glasses be dispensed with?

Principally in hypermetropia in the slighter degrees and especially in young people where the accommodation is active and vigorous, and no symptoms of asthenopia are in evidence.

A person aged 40 can just see distant objects clearly with a minus 1.50 D. lens. What glasses, if any, would be required for reading at 14 inches? What reading glass would be required at double his age?

We will assume that the − 1.50 D. lens represents the amount of myopia present.

The average amplitude of accommodation at 40 years of age is 4.50 D., which in this case is increased by the myopia to 6 D., of which he is able to use comfortably from one-half to two-thirds, or 3 D. to 4 D. At 14 inches 2.75 D. of accommodation is necessary, so that it is evident there is still a surplus of accommodation and no glasses will be necessary for reading.

At 80 years of age, when the accommodation is entirely lost, he would theoretically need + 1.25 D. lenses, which added to the 1.50 D. of myopia would give the 2.75 D. necessary for reading

at 14 inches. But practically on account of the senile diminution of refractive power it is likely the glasses will have to be stronger than 1.25 D.

In cases of esophoria where is the base of the prism to be placed, in or out, and how should strength or number of prism be determined for exercising the same, and the proper way of exercising?

For the correction of esophoria the base of the prism is placed out.

If the esophoria was supposed to be due to weakness of the external recti and it was desired to exercise the same, the apex of the prism must be placed over the muscle to be exercised, which in this case would be base in.

First it must be determined how much these muscles are able to overcome. Normally these muscles have a strength of 6° to 8°. If they were weak this might be reduced to 1° or 2°, but this must be determined as a starting point, and then the strength of the prisms gradually increased until the normal standard is reached.

A certain patient is astigmatic, presbyopic and hypermetropic. In what order are these defects tested for?

We examine for errors of refraction first and of accommodation next. Of the errors of refraction we commence with the spherical errors, hence the order would be: Hypermetropia, astigmatism and presbyopia.

If a 6° prism is placed in front of an eye with both eyes in use, in what direction does the base of the prism have to be in order that there might be diplopia?

If placed base out, it would be quickly overcome by the internal recti. If base in, there is some question whether it could be overcome by the external recti, and there *might* be diplopia. But if placed vertical there would surely be diplopia.

An eye is hypermetropic 4 D., of which 1 D. is latent. What will be his far point with a + 6 D. lens?

If the latent hypermetropia refused to accept correction there would be 3 D. of manifest hypermetropia. Then the 6 D. lens would represent an overcorrection of 3 D., or an artificial myopia of this amount, which would be represented by a far point of 13 inches.

What proportionate amount of ametropia should be corrected in a person 20 year of age, and how much should be corrected in a person 50 years of age?

In a person 20 years of age we might correct one-half to two-thirds of the ametropia, or perhaps it would be safer to say, the manifest defect. In a person 50 years where the accommodation for distance need scarcely be reckoned with, the full correction may be given.

If an addition to a prescription for distance glasses must be made for presbyopia of + 3.50 D. or more, what error in the prescription for distance should be estimated?

If the distance glasses were convex we would suspect that the hypermetropia had not been fully corrected, because the presbyopic addition is scarcely ever more than 3 D.

What is the Maddox rod, and for what is it used?

It is a strong cylinder of glass, either white or red, which elongates a point of light into a long, narrow streak of light at right angles to its axis, and is used in the detection of the various forms of heterophoria.

Can the subjective test be made at less than 20 feet; that is where 20 feet is not available?

Yes, if allowance is made for the increased divergence of the rays from the shorter distances. For instance, if the test is made at a distance of 10 feet the rays would have a divergence of 120 inches, which is equal to .33 D., which must be subtracted from the convex correction and added to the concave.

Some operators prefer to use a mirror, which in a 10-foot room gives the effect of 20 feet.

Where should the base of the prism be placed in measuring powers of adduction, abduction, supraduction and infraduction?

The apex of the prism is placed over the muscle to be tested; hence adduction is measured by prism base out, abduction base in, supraduction base down, and infraduction base up.

Which test do you think the most accurate for muscle imbalance?

There may be some difference of opinion on this point, but for all practical purposes we should say the Maddox rod test.

In cases of anisometropia what is the greatest amount of difference in lenses which can usually be worn for comfortable binocular vision, and why?

This is an open question, as the difference varies in each case. Some authorities would fix the limit at 2 D., but we have knowledge of cases where the difference was as great as 5 D. This is a point that cannot be determined by any rule, but only by actual trial.

Is the test with the perimeter subjective or objective, and why?

This is a subjective test, because the information to be gained is dependent upon the answers of the patient.

A myope of 5 D. has an amplitude of accommodation of 2 D. What lenses would you prescribe for reading music at 50 cm. so as to permit the use of one-quarter of his power of accommodation?

The full amplitude of accommodation is 2 D., but he is to be permitted to use only .50 D. In order to see at 50 cm. without any accommodation a + 2 D. lens is required, but as this patient is allowed to use .50 D. of his accommodation then only + 1.50 D. is necessary, which added to his distance glasses would reduce them to − 3.50 D.

How should presbyope be tested for muscle balance at fourteen inches?

The usual method is by means of the dot and line test and a vertical prism. Of course, the necessary convex lenses must be worn and care be taken to see that they are properly centered for the fourteen-inch distance, as otherwise the lenses themselves will introduce a prismatic effect.

The Maddox rod may also be used with a small point of light at the indicated distance of fourteen inches.

Under what conditions would you consider it unwise to advise the use of distance glasses, even though ametropia were present?

If any disease of the eye calling for the attention of a medical man was known to be present, or even strongly suspected, it would not be wise for an optometrist to prescribe glasses, even though an error of refraction was also discovered.

Write a hypothetic prescription involving prisms, spheric and cylindric lenses.

$+ 1.50$ D. sph. $\bigcirc$ $+ .50$ D. cyl. axis 90° $\bigcirc$ prism 2° base in.

A + 4 D. sphere is placed before an eye that is 2 D. hypermetropic, and an object twenty inches away is looked at. What will be the character of the image on the retina?

In order to see an object at a distance of 20 inches the emmetrope will use 2 D. of accommodation; the hypermetrope, in addition, must use sufficient accommodation to overcome his error; therefore, in the case mentioned, 4 D. of accommodation will be required at 20 inches. If now a + 4 D. lens is placed before the eye the result will be a distinct image upon the retina without effort of accommodation.

When the targets of an ophthalmometer overlap at an angle of 120° and separate at 30°, what will be the axis of the concave cylinder?

This would indicate that the greatest refraction was located in the 120th meridian and the least in the 30th meridian; therefore, the axis of a concave cylinder would coincide with the latter.

Upon what general principles are the various tests for muscle imbalance based, and what is a main objection to these tests?

There are two general principles on which the various muscle tests are based:

1. Those which displace the image in one or both eyes from the macula and thus produce an artificial diplopia.
2. Those in which the image formed in one eye is changed in color, size or shape, which dissimilarity in the two retinal images causes diplopia.

In both instances binocular vision is destroyed, and a weakness in any of the muscles is supposed to manifest itself.

The objection to the first class of tests is the displacement from the macula, but in both of them we have no means of knowing how much innervation is sent to the several muscles and how much of the heterophoria may thus be made latent.

If a presbyope wearing a convex lens moves it farther from his eye what is the change in dioptric power?

The effect of moving a convex lens farther from the eye is to increase its dioptric power.

If a + .50 D. sphere gives best vision on the horizontal lines of the astigmatic fan, and a + 1 D. sphere best vision on the vertical lines, what is the prescription for the correcting lens written in three different ways?

+ .50 cyl. axis 180° $\bigcirc$ + 1 cyl. axis 90°
+ .50 D. sph. $\bigcirc$ + .50 D. cyl. axis 90°
+ 1 D. sph. $\bigcirc$ − .50 D. cyl. axis 180°

In trying minus lenses on a myope what principal rule would you constantly keep in mind? What rule in cases of hypermetropia, using plus lenses?

In myopia the weakest concave, to impose as little tax upon the accommodation as possible.

In hypermetropia the strongest convex, to assist the accommodation as much as possible.

The distance test shows that a certain patient is 1.25 D. hypermetropic, but the dynamic test with the cross cylinder at 20 inches shows that a + .25 sphere cause neutrality. What glasses would you prescribe?

Not stronger than + .25 D., at least to start with.

What are "cover" tests and what is their object?

A screen or card is placed before one eye, which is watched to discover if it makes any movement when thus covered. If not orthophoria is indicated. If it moves outward there is a presumption of esophoria; if it moves inward a presumption of exophoria.

On what principle does the Maddox rod test act?

That it causes a retinal image so dissimilar in size, shape and appearance from the other that the natural instinct to fuse them into one is for the time being destroyed, and in this way a deficiency in any of the muscles becomes manifest.

Under what circumstances would you recommend the constant wearing of glasses?

When distant vision is impaired, when headache and symptoms of asthenopia are present, in high errors of refraction and usually in all cases of astigmatism.

What acuity of vision would you expect to find in a young case of mixed astigmatism, in which the corrected cylinder would be 50 D. or less, with the rule? Against the rule?

In a case of mixed astigmatism the accommodation is apt to be brought into play to overcome the hypermetropic meridian, and in so doing it makes the myopic meridian more myopic. When the astigmatism is with the rule it is the vertical meridian that is myopic, which is the meridian that focuses horizontal

lines. But as the visibility of letters largely depends upon their vertical lines, under these circumstances vision would be little if any impaired.

In astigmatism against the rule the horizontal meridian is the myopic one, and as this is the meridian that focuses the vertical lines vision is more likely to be impaired.

Under what circumstances should hypermetropes be given full correction?

When patient is past middle age, distant vision impaired and the hypermetropia practically all manifest.

When a high degree of esophoria or convergent strabismus is associated with the refractive error.

When a partial correction fails to afford relief.

What is the effect on the ciliary muscles of giving a full correction in the case of hypermetropes?

The ciliary muscles are relieved of all effort in distant vision, and are called into use only for the accommodation necessary in near vision, just as is the case in emmetropia.

Where is the base of the prism placed when the eye turns in? That is, for constant wear. And where placed to exercise the muscles?

Base out for constant wear and base in for exercise.

How can we with a stenopaic disk find an error of a vertical meridian in a case of astigmatism which requires for correction a + 50 D. cylinder axis 180°?

The stenopaic disk is placed over the vertical meridian of the eye and the amount of hypermetropia in this meridian measured by the acceptance of convex lenses, or, better still, by the fogging method.

In a muscle test with a single prism over the right eye base down the upper image is seen on the left. What is the nature of the heterophoria and how can it be measured?

The upper image is that of the right eye, and being seen on the left eye indicates exophoria. It can be measured by strength of prism base in that it brings the two lights in the same vertical plane.

How can the near point of convergence be found objectively? Subjectively?

By the near point of convergence is understood the closest point for which the eyes can converge. In order to measure it a small fixation object is held in front of the eyes and gradually brought closer and closer.

In the objective test the eyes are sharply watched, and as soon as one of them ceases to converge or commences to diverge the near point of convergence has been reached.

In the subjective test the object is approached until it is seen double by the patient.

A myope of 4 D. has an amplitude of accommodation of 3 D. He is to be fitted with glasses to read at 16 inches, but must use one-half of his accommodation. What must be the power of his glasses?

The positive refractive power of such an eye would be equal to the sum of the amplitude of accommodation and the myopia, or 7 D. In order to read at 16 inches 2.50 D. of accommodation is necessary, but if he must use only one-half of his accommodation then he should possess 5 D. In order to bring about this result the power of the glass required would be − 2 D., which reduces the 7 D. of accommodation to the desired amount.

When plus lenses are decentered in, what extrinsic muscles are assumed to be at fault?

The effect produced being that of prisms bases in, the internal recti would be assumed to be weak.

A patient giving his age as thirty-five years requires + .50 D. for distance and + 2 D. for reading. What would you suspect?

Would suspect that the + .50 D. did not represent the full correction for distance, but that the amount of hypermetropia was more nearly equal to 2 D. and that the proper tests had not been made to uncover the latent error.

In two given cases, each patient's age being thirty years, neither having worn glasses before, normal vision is obtained with spherical correction. One is hypermetropic 2 D. and has 2° of exophoria; the other is myopic 2 D. and has 2° of esophoria. Write prescriptions for both.

When hypermetropia occurs in connection with exophoria, and myopia in connection with esophoria, there is a disturbance of the normal relation that should exist between the accommodation and the convergence.

In the first case we would be inclined to undercorrect the hypermetropia because convex lenses tend to aggravate exophoria; or we would combine a prism base in to correct the exophoria, not exceeding one-half the amount of insufficiency.

In the second case we would also think of undercorrection, because a concave lens tends to increase an esophoria; or we would combine a prism base out with the concave lens, not attempting to correct more than one-half the heterophoria.

What course should be followed in prescribing for anisometropes whose eyes differ widely in refraction?

Correct the best eye fully and the other eye approximately. In other words, take care of the good eye and do what you can for the poorer eye at the time, with the thought of gradually increasing the correction of the latter, as the comfort of the eyes will allow. The visual acuity of each eye, as well as the muscle balance, must be taken into account. It is impossible to give general directions that will apply to all cases, but each case must be managed on its own merits.

Give reasons why it is sometimes not advisable to prescribe distance glasses.

When the acuteness of vision is not impaired, when the refractive error is small, when there is no headache or photophobia or evidence of eyestrain in general vision, and when glasses cause so much fogging of distant vision as to be unbearable.

Under what conditions should the constant wearing of glasses be insisted on?

In case of strabismus due to refractive error, in almost all cases of astigmatism, when headache is present due to eyestrain, and when vision is very greatly improved by the glasses.

Under what circumstances might a concave lens be prescribed for a hypermetrope?

The optical student is so much cautioned about the danger of giving concave lenses to a hypermetrope that when he gets into practice he would not want to be accused of such ignorance as this question would seemingly display. And while this teaching is correct, there are cases of hypermetropia with insufficient convergence, in which it might be allowable to prescribe concave lenses for temporary use for their indirect effect of stimulating the convergence.

Give reasons for and against full correction of myopia and hypermetropia in (*a*) *orthophoria and* (*b*) *heterophoria.*

(*a*) In orthophoria, we give the strongest convex lens in hypermetropia and the weakest concave lens in myopia, in order to assist the accommodation or lessen the strain upon it.

(*b*) In heterophoria, the above rule must be modified in the light of the effect of the lenses upon the accommodation and convergence.

When hypermetropia has esophoria associated with it, the full correction is given; but when exophoria is present, it is best to under-correct, because convex lenses aggravate exophoria.

In the case of myopia with exophoria, the full correction may be given; but when esophoria is present, the concave lenses

should not be too strong, because concave lenses aggravate esophoria.

What is the usual method of employing the stenopaic slit in testing the eye, and why is it not in common use?

While the patient looks at the card of test letters the slit is rotated to the meridian of best vision, in which position trial lenses are used to determine if this meridian is emmetropic, hypermetropic or myopic. The slit is then rotated to the meridian at right angles where test lenses are used to determine if it is hypermetropic or myopic. Having estimated in this way the refractive condition of the two principal meridians, it is easy to formulate the cylinder or sphero-cylinder that is required to correct.

It is scarcely reliable because the accommodation is likely to come into play and may be used more in one meridian than the other, thus impairing the accuracy of the test.

When may myopes be given the strongest possible lenses to produce normal vision?

The standard advice to prescribe the weakest concave lenses in myopia may be modified in young people when exophoria is present.

Of two equally farsighted persons, one has the habit of wearing his spectacles low down on his nose, the other wears them close to his eyes. Which should have the stronger spectacles, the object being held at the same distance from the eye by both persons? Give the reason for your answer?

It is a well-known fact that convex lenses increase in power as they are pushed farther from the eye. In these cases we are led to infer that they are both under-corrected. In the first case the person has learned that he can get the extra power that is needed by wearing his spectacles low down on his nose.

The second person either has not learned this trick or he prefers to wear his glasses in their proper place close up to the eyes, and therefore he is the one that should have stronger spectacles.

A patient with a pupillary distance of 59 mm. wears + 4 D. lenses for distance in a spectacle frame with a pupillary width of 61 mm. What is the effect of the lens and what is the amount?

Under these conditions patient would not look through optical centers of lenses and therefore a prismatic effect would be produced; and as the spectacle frames are too wide for the pupillary distance of the patient, and as the lenses are convex, the prismatic effect would be bases out.

Figuring on the basis of 1° of prism for every 1 D. decentered 10 mm., and as the amount of decentration in this case is 2 mm., the amount of prismatic power developed would be 4/5° for each lens.

Patient aged forty-five has worn + 1 D. cyl. axis 180° with comfort for years previously, but now complains that reading in evenings is uncomfortable. What would be your treatment of the case?

This patient has now reached the presbyopic period of life, and the cylinders worn for the correction of his refractive error will no longer suffice for close use, but must be supplemented by the addition of convex spheres for the correction of the presbyopia, which at this age would probably be about + 1 D.

I would re-examine his eyes and ascertain just what is needed for distance and for reading, and give him the choice between bifocals and two pairs of glasses. If separate pairs of glasses are ordered for close use, it is more than probable the cylinders may be reduced somewhat, as is usually the case with convex cylinders having a horizontal axis, because of the fact that when looking down through convex lenses, as in reading, there is produced the added effect of a cylinder with a horizontal axis, thus allowing the cylindrical surface of the lens to be reduced somewhat.

In the case of astigmatic presbyopes is it always necessary to retain the cylinder in the reading glasses? And what is the cause of the difficulty experienced by presbyopes in getting accustomed to wearing cylinders?

As a rule, if the astigmatism is of such a character as to cause symptoms of discomfort, it will be corrected earlier in life,

and then when the patient reaches the presbyopic age, it simply means the addition of a convex sphere of such power as will afford comfortable reading at the proper distance.

But it sometimes happens that persons who have passed their fortieth year will apply for glasses, with the history that they have never worn them, or felt the need of them, but of late they are beginning to experience some difficulty in close vision.

The optometrist starts to make his examination in the usual way and soon finds the existence of astigmatism, perhaps .50 D. to 1 D. He remembers that he was taught that astigmatism is a frequent cause of eyestrain and headache, and if he has not had much practical experience he will proceed to correct it and perhaps get himself into trouble, because the patient returns and complains that the glasses are uncomfortable.

Another examination will show the presence of the same amount of astigmatism as at the first, and perhaps the patient will be advised to persevere with the sphero-cylinders, but with probably the same result as before.

This brings up the question as to why it is more difficult for older persons to become accustomed to cylinders than younger ones. Now, it must be borne in mind that vision is not so much a question of physical optics as of physiological optics, and that there is a psychological feature as well; in other words, there is not only the formation of an image on the retina, but also the interpretation of that image by the brain. It is not the eye that sees but really the brain.

Astigmatism causes some distortion in the retinal image, but it is not noticeable to the patient, because it has always existed, and, in fact, the sense of vision was acquired and cultivated with that kind of an image. For instance, a square object would not form a perfectly square image in an astigmatic eye, but would be elongated in one direction or the other, according to the character of the error.

The person, however, knows by education and experience that the object is actually square and his brain learns to interpret the slightly distorted retinal image as that of a square object, and he is satisfied with his vision.

When the proper correcting cylinders are placed before the eye, the image of a square object is also square; but it is different from what the brain has been accustomed to recognize as a

square object, and hence, even though the image is square, the object appears to be elongated.

The greater number of the cylinders that are worn are prescribed more for the relief of asthenopia than for the improvement in vision; but even in the higher degrees of astigmatism where the acuteness of vision is much less than normal, the correcting cylinders, though they afford perfect vision, are oftentimes disappointing and unsatisfactory for the reasons mentioned above. The patient is expecting great things and when he finds that the results are not as good as before, he is apt to become disgusted.

A myope of 6 D. possessing 3 D. of accommodation, wants a pair of glasses for reading at 16 inches. If it is desired that only one-half the power of accommodation be used, what would be the strength of the glasses you would give?

In determining the reading glasses in high myopia, the rule is as follows: Subtract the glass representing the desired reading point from the full measure of the myopia. In this case the glass representing the desired reading point of 16 inches is 2.50 D., which we subtract from the full amount of myopia which is 6 D., and the result is − 3.50 D.

With these − 3.50 D. glasses there remains an uncorrected myopia of 2.50 D., which represents a far point of 16 inches, at which distance the person would be able to read without any effort of accommodation.

But we are told it is desired to use one-half of his 3 D. of accommodation and, therefore, to bring this amount of accommodation into action, a − 1.50 D. lens must be added to the − 3.50 D. lens, which means that the glasses to be prescribed to accomplish the purpose indicated must be − 5 D.

Can a concave lens have conjugate foci? If so, under what conditions?

When parallel rays of light enter a concave lens, they are made divergent to such an extent as to appear to come from the principal focal distance of the lens. If the power of the lens is − 4 D., the rays after refraction will apparently diverge from a point 10 inches in front of the lens.

But when the rays proceed from an object nearer than infinity, in other words when the rays that enter the lens are already divergent, they are made still more divergent by the action of the lens. The divergence produced by the lens is increased by the divergence caused by the nearness of the object, and, therefore, the rays will appear to diverge from a point closer than the principal focus, which point would be conjugate to the object.

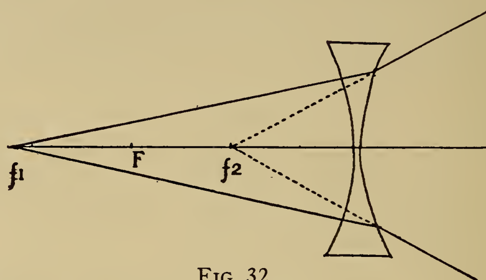


FIG. 32

In this diagram it will be seen that the rays diverging from f_1, which is the location of the object, will be still more diverged by the action of the lens so as to appear to proceed from f_2, which is assumed to be the location of the negative focus and is conjugate to f_1.

Suppose in the above diagram the lens is an 8-inch concave, and the distance of f_1 is 40 inches; then the rays enter the lens with a divergence of 1/40, to which is added the divergent power of the lens, which is 1/8, and the rays after refraction will have a divergence

$$\frac{1}{40} + \frac{1}{8} = \frac{6}{40} = \frac{1}{6\frac{2}{3}}$$

f_2 is negative and 6 2/3 inches in front of the lens.

If rays diverge from 40 inches to an 8-inch concave lens, they are after refraction divergent as if from 6 2/3 inches.

If a patient comes to you wearing + 1 D. spheres for distance and + 6 D. spheres for reading, would this seem right to you? If not, point out where the error is likely to lie.

We must assume that this is a case of hypermetropia with presbyopia, and as such the history would be more complete if we knew the age of the patient. However, we will consider the

presbyopia as complete, or in other words that the amplitude of accommodation has been entirely lost.

Under such circumstances the focal distance of the lens required for reading should correspond to the desired reading distance, as, for example, with entire suspension of accommodation a + 2.50 D. lens would afford a reading distance of 16 inches, a + 3 D. lens, a reading distance of 13 inches, and so on.

The latter has come to be regarded as a proper reading distance, and therefore, the strength of the lens required even in total presbyopia is seldom more than 3 D. or perhaps + 3.50 D.

When we come to consider this case we see that there is an addition of 5 D. apparently to correct the presbyopia, which, in view of the above, is too much. Now, then, it is probable that the + 6 D. lenses are necessary to afford clear vision at the customary reading distance, and therefore we would infer that instead of the reading glasses being too strong, the distance glasses are too weak.

This error is probably due to the carelessness of the optometrist who made the examination. He, perhaps, placed the + 1 D. lenses before the patient's eyes, which caused a marked improvement in distant vision and which the patient may have declared splendid. And on such declaration the glasses were prescribed, instead of following the rule to find the *strongest* lenses that afforded good distant vision.

We think a further examination of such a case would show that the hypermetropia was probably equal to 3 D. with an addition of a similar amount needed for reading.

Define paresis and paralysis. Tell how you would diagnose each condition.

The words paresis and paralysis are often used interchangeably, but usually the former is understood to apply to milder cases. Paralysis is applied to that condition where there is a loss of power of motion or sensation, and paresis to that condition in which there is a slight form of paralysis.

If there is paralysis in the internal rectus there would be a total loss of the power to turn the eye inwards. The eyes may assume a position of parallelism, but there is more likely to be a slight divergence, which would result in crossed diplopia, which is increased by trying to converge or look inwards, and diminishes or disappears when looking outwards or away from affected muscle.

In paresis the limitation of movement would be less noticeable and the strabismus and diplopia would be less observable, perhaps only detectable when extreme convergence is attempted.

What is the difference between conjunctivitis and keratitis?

The first is an inflammation of the conjunctiva and the second of the cornea.

The symptoms of conjunctivitis are congestion of the ocular palpebral conjunctiva, a burning and scratching as if sand was in the eye, a discharge—at first watery, afterwards mucopurulent; vision but slightly impaired, photophobia not very marked, slight swelling of the lids.

The symptoms of keratitis indicate great irritability. Marked photophobia, excessive lachrymation and circumcorneal injection. Vision blurred on account of infiltration of the layers of the cornea. Blood vessels are seen in the cornea. Pain is considerable. The inflammation may extend to the iris (iritis) and even to the ciliary body and choroid.

Describe hemorrhage of the retina.

Hemorrhage may occur in any layer of the retina or in any portion of its surface. Its color is at first bright red, later it becomes darker, and may finally be entirely absorbed.

The most common seat of retinal hemorrhage is in the region of the disk and next in the neighborhood of the macula, the latter disturbing vision more and more as the macula is approached. Hemorrhages occur mostly between the fibers of the inner layer and present a flame-shape appearance. Those which occur in the outer layers are more apt to be round or irregular in shape.

A hemorrhage may sometimes be so profuse as to break through the hyaloid membrane and escape into the vitreous.

The causes of retinal hemorrhage are degeneration of the walls of the blood vessels as found in advanced life, heart disease, sudden reduction of tension, as after the operation for glaucoma, pernicious anæmia, gout, etc.

What is complete dislocation of the lens called?

In complete dislocation of the lens the optical condition is one of aphakia; that is, high hypermetropia and entire loss of accommodation.

Name a disease of the eyes on account of which immigrants are refused admission to this country. Give reason.

Trachoma, because of its contagiousness, due to the presence of a micro-organism in the discharge. It has a tendency to spread in certain countries, among certain races and in crowded institutions. Bad air, overcrowding, poor food and filth contribute to its development in connection with the contagion.

What is pterygium?

Pterygium is a vascular thickening of the conjunctiva, triangular in shape, on the nasal side of the cornea, with the apex of the growth towards the latter. Sight is not impaired unless the pterygium extends over the pupillary region of the cornea. The treatment, if any is required, is surgical.

What is color blindness?

Complete color blindness would mean an entire absence of the color sense in which case a landscape would look like an engraving—a picture entirely colorless. This, however, is very rare.

Partial color-blindness, as it is usually encountered, is due to a loss of sensation for one of the three fundamental colors, red, green and violet. Red color-blindness is the most common. This defect is found most frequently in men and is doubtless to some extent a matter of education.

What is conical cornea?

A diseased condition in which the cornea is altered in shape and bulges forward in the form of a cone. This is due to a gradual atrophic process in the central part of the cornea, as a result of which the intraocular tension causes it to bulge. The transparency of the cornea is not much impaired. The condition is easy of diagnosis because it is evident on mere inspection.

What is color blindness and what effect does it have on visual acuity?

Color blindness is an inability to distinguish between certain colors. As a rule, it does not impair the visual acuity, nor interfere with reading, writing or the ordinary occupations of life.

Of what does the operation for cataract consist?

In the removal from the eye of the crystalline lens, which has lost its transparency and become opaque.

What causes a posterior staphyloma?

This is a bulging backward of the eyeball and occurs in high myopia. In these cases there is usually an increased pupillary distance, which in connection with the close position at which work is done imposes an unnatural tax upon the con-

vergence. This latter pressure from tension of the recti muscles tends to an elongation of the ball, which is facilitated by the softening of the tissues of the posterior half of the eye, due to the accompanying scleritis and choroiditis, which is so common in myopia.

What is aphakia?

A condition of the eye in which the crystalline lens is absent, either naturally or artificially, as in the operation for cataract.

What is glaucoma, and name one prominent symptom?

A disease which seriously threatens vision on account of abnormal intraocular tension, and its one prominent symptom is a stony hardness of the eyeball.

What part of the eye is affected in conjunctivitis?

The mucous membrane called the conjunctiva.

What part of the eye is affected in iritis?

The iris.

What would lead you to believe that your patient was suffering from cataract?

The oncome of second sight would at once lead to the suspicion of cataract. In such cases there is a condition of refractive myopia, due to a softening and swelling and, as a result, an increase in power of the crystalline lens. This is apt to occur in the 60's, and such a person who has been depending upon convex lenses for reading now finds he is able to read without glasses. This is almost invariably a premonitory symptom of cataract.

Also if smokiness of vision and spots before eyes were complained of cataract would be suspected. In advanced stages of the disease cataract is easily detected even in ordinary daylight by the grayish appearance of the pupil. In the earlier stages

cataract is discovered by an ophthalmoscopic examination, the opacities showing as dark spots on the red background.

What is meant by the expression "woolly" appearance around the edge of the optic nerve?

This term is used to express the appearance of the disk in papillitis or inflammation of the optic nerve head, in which the disk is swollen, red and with a blurring of its border by a grayish opalescent haze. This haziness may become a decided opacity, covering and extending beyond the border of the disk, and later pass into a condition of atrophy.

A person cannot see distant objects clearly. What are the possible reasons?

In a general way we say the impairment of distant vision may be due either to refractive error or disease.

Any error of refraction, myopia, hypermetropia or astigmatism may be the cause of it, especially myopia and high degrees of hypermetropia and astigmatism.

In regard to diseases there may be cataract or opacity of any of the refracting media and affections of the optic nerve and retina.

What is the cause of strabismus in young children?

During the first few months of life the movements of the eyes are uncertain and are not controlled by the brain. It is not until the end of the first year that binocular vision is established. In the absence of the natural desire for binocular vision there is no incentive for accord between the movements of the two eyes, under which circumstances any slight cause may upset the equilibrium of the higher centers of the brain. Hence babies often squint from gastric or other disturbances.

But in the great majority of young children where the strabismus is of the convergent concomitant form and appears by the fourth year, it is due to hypermetropia, which is the predominant error of refraction in children and which imposes an extra tax on the accommodation, and thus stimulates the convergence.

What is mixed astigmatism and what kind of a lens is required to correct it?

That condition in which one meridian is hypermetropic and the other meridian at right angles is myopic. It is corrected by a cross-cylinder, the convex element of which corrects the hypermetropic astigmatism, and the concave element the myopic astigmatism. The axes of the cylinders are at right angles to each other, and this cross-cylinder may be transposed to a sphero-cylinder.

The far point of a myope is at 10 cm. and his near point is at 5 cm. What is his myopia and what is his accommodation?

His myopia as estimated by his far point is 10 D. and his amplitude of accommodation as shown by his near point is 20 D.

What is meant by the terms astigmatism with the rule and astigmatism against the rule?

Usually the normal eye shows a slight excess of curvature in the vertical meridian of the cornea; hence in any case of astigmatism where the vertical meridian exceeds in refractive power we term it "with the rule," and where the horizontal meridian is in excess, "against the rule."

What kind of astigmatism cannot be satisfactorily corrected with glasses, and why?

Irregular astigmatism, because in these cases there is a difference in refraction in different parts of the same meridian, and it is obvious that glasses could not be ground in such a way as to correct this condition.

What kind of strabismus, if any, is usual with pronounced hypermetropia?

Convergent concomitant strabismus, on account of the close relation existing between accommodation and convergence. In hypermetropia where the accommodation must be used in excess of normal, the convergence is stimulated into excessive action and manifests itself by a turning in of one or the other eye.

The far point of a certain eye is 33 cm. behind the eye, and the near point is 33 cm. in front of the eye. What is the character of the refractive error, and what is the amplitude of accommodation?

Hypermetropic to the extent of 3 D. and an amplitude of accommodation of 6 D. to overcome the hypermetropia and show a near point of 33 cm.

The far point of an eye is 1/3 of a meter in front of the eye. What is the kind of error, and what lens is required to make this eye emmetropic?

Myopia, requiring a − 3 D. to make it emmetropic.

An eye is hypermetropic 2 D. in the vertical meridian and 2.50 D. in the horizontal. Write four different prescriptions of glasses to fully correct the error of refraction.

+ 2 D. cyl. axis 180° $\bigcirc$ + 2.50 D. cyl. axis 90°
+ 2 D. sph. $\bigcirc$ + .50 D. cyl. axis 90°
+ 2.50 D. sph. $\bigcirc$ − .50 D. cyl. axis 180°
Toric + 6 D. vertically + 6.50 D. horizontally with − 4 D. for inner surface.

An old person has no accomodation left. To see distinctly at 33 cm. he required + 2.25 D. sphere. What would be the prescription for distance and for reading music at 80 cm.?

In order to see distinctly at 33 cm. without effort of accommodation a + 3 D. lens would ordinarily be required; but as in this case it was possible with a + 2.25 D. lens, we must assume that the other .75 D. is supplied by the eye, which could be done only if the eye was myopic to that extent.

For vision at 80 cm. without accommodation a + 1.25 D. lens would be called for, which in this case, where the refraction is myopic, .75 D. would be reduced to + .50 D.

Therefore the prescriptions would be as follows:

Distance − .75 D.; at 80 cm. + .50 D.

In cases of myopia when may this condition be expected to show itself?

During school life, when the eyes are taxed to the utmost perhaps with insufficient light and under unfavorable conditions, the first indication being a tendency to hold the book close to the eyes.

What is the far point of an eye which needs a — 6 D. to make it emmetropic?

About six and a half inches.

What is the difference between latent strabismus and heterophoria?

No practical difference, as both terms are used to express the same condition.

In the case of anisometropes one retinal image may be larger than the other, and, therefore, the two eyes cannot act together. How can we settle this point?

By placing before each eye its proper correction and directing the patient's attention to a single line of letters across the room. A 5° prism is placed vertically before one eye and the patient will see two lines of letters, one under the other, one belonging to each eye. The patient is asked which is the plainer, the upper or the lower. In this way can be quickly determined which eye has the best vision and an effort made to improve that of the poorer eye so as to place them as nearly as possible on an equality.

The general rule in anisometropia is to take care of the good eye and give it its proper correction, with an approximate correction to the other eye for the time being, which can later be raised more and more to full correction.

In a case showing by the trial case test a full correction with — .50 spheres, what would lead you to suspect that there was a spasm of accommodation?

Inasmuch as hypermetropia is the predominant error of refraction, and as its detection is important because it is the chief cause of eyestrain, it is proper to suspect this error in all cases until proved otherwise. Slight degrees of myopia are few, and as weak concave lenses are readily accepted by all young people such acceptance should at once raise the suspicion of spasm of accom-

modation, and then the fogging system must be patiently and persistently used.

What is the cause of presbyopia and when does it begin?

Due to the increasing firmness of the crystalline lens, on account of which it is no longer able to respond to the efforts of the ciliary muscle to cause it to assume an increased convexity. As a result the near point commences to recede from the tenth year, but presbyopia cannot be said to begin until the near point has receded beyond eight inches, as until that time near vision is but little interfered with.

What causes the recession of the near point?

Lessening of the amplitude of accommodation, as naturally occurs in presbyopia.

What two fundamental reasons are there for the oncoming of presbyopia?

Weakening of the ciliary muscle and increase in firmness of the crystalline lens, so that it can no longer respond to the action of the muscle in the effort to augment its convexity.

If there is a tendency of the visual axes of the two eyes to diverge, what is the condition called? Suppose the deviation actually exists, then what is the name of the condition?

Tendency to divergence, exophoria. Actual divergence, exotropia.

When a person of thirty years of age, who is an emmetrope or close thereto, has to wear glasses for near vision, what condition is probably present?

When a person at this age begins to need convex lenses for reading we at once suspect hypermetropia. But as the question intimates a condition of approximate emmetropia the condition must be one of deficient or subnormal accommodation.

When the retinal images of an object on the two retinas fall on such retinal points that the two images cannot be fused into one, what is the result and what is the condition called?

Double vision or diplopia; and if there is a deviation of one eye, strabismus.

Define anaphoria, cataphoria and hyperphoria.

Anaphoria is that condition in which there is a tendency for the eyes to turn above the normal position, as a result of which the head must be bent forward.

Cataphoria is that condition in which there is a tendency for one visual line to deviate below the other, and in hyperphoria above the other.

What name is given to that condition where one eye is hypermetropic or myopic and the other eye is more so? When one eye is hypermetropic and the other is myopic?

Anisometropia is the general term in use, although the latter may be called antimetropia.

The punctum remotum of a patient twenty years old is seven inches and vision is improved by a concave lens. What condition exists?

Myopia of approximately 5.50 D.

How could you objectively measure the deviation of a squinting eye?

One of the most reliable methods is by means of the arc of a perimeter. The squinting eye should be in the center of the arc, while the fixing eye should be engaged with some distant object across the room. The angle of deviation is found by moving a lighted candle along the arc of the perimeter until the reflection of the flame appears to occupy that portion of the cornea which is directly over the center of the pupil, when the eye of the observer is behind the flame. This locates the optic axis of the eye and the amount of deviation can be measured and read off the scale that is printed on the arc of the instrument.

How would you subjectively measure the deviation of a squinting eye?

This is possible only when diplopia can be made evident. Ordinarily in strabismus the squinting eye is amblyopic and vision is monocular; but by exercise of the deviating eye to improve its vision and by placing a colored glass over the fixing eye to lessen its domination, it may become possible for the patient to discern two lights. When once this is accomplished there is no difficulty in measuring the deviation by the prism that is required over the squinting eye with its base opposite to the deviation that will fuse the two lights.

What would lead to a suspicion of paralytic strabismus?

When there is limitation of movement of eye in one direction.

Diplopia, which is confined to one portion of the field and is increased the more the eyes are turned in this direction.

Secondary deviation of the sound eye exceeding the primary deviation of the affected eye.

A strabismus that is noticeable only in certain positions.

What are the conditions in the following cases: Parallel light is focussed on the retina; in front of the retina; behind the retina; part focussed in front of the retina and part behind?

Emmetropia, myopia, hypermetropia, astigmatism.

What is the difference in meaning of anaphoria and hyperphoria, and can the two conditions be present at the same time?

Anaphoria signifies an upward tendency of both eyes together, the visual lines remaining parallel to each other.

Hyperphoria signifies a tendency of the visual line of one eye to place itself above that of the other, thus causing a departure from parallelism of the visual lines.

It is evident that these two conditions could not exist in the same case at the same time.

What must be the character of the incident rays of light in order that they may focus on the retina when it is situated nearer than the principal focus of the dioptric system?

The rays must be convergent as in hypermetropia, where they are made so by the correcting convex lens.

What must be the character of the incident rays of light in order that they may focus on the retina, when it is situated beyond the principal focus of the dioptric system of the eye?

The rays must be divergent as in myopia, where they are made so by the correcting concave lens.

What is the condition of hypermetropia when the accommodation conceals a part of the error, and what term is applied to the part of the error not so concealed?

Latent when concealed by the accommodation and manifest when not concealed.

$$- .12 \text{ D. sph.} = + .25 \text{ D. cyl. axis } 140°$$

What will be the refractive condition of the two principal meridians of an eye requiring the above?

.12 D. hypermetropic in the 50th meridian and .12 myopic in the 140th meridian.

What kind of astigmatism will cylinders correct, and what kind will they not correct?

In regular astigmatism in which there are two principal meridians at right angles to each other, one of least and the other of greatest refraction, cylinders supply the needed power in the desired meridian to produce equalization.

But no glass can be ground to correct irregular astigmatism, in which there is a difference in power in different parts of the same meridian.

Name the two spherical errors of the eye and state how they are corrected?

Hypermetropia, in which there is assumed to be a deficiency of refractive power, and is corrected by a convex lens to supplement the deficiency; and myopia, in which there is an excess of refractive power and is corrected by a concave lens to reduce the excess.

What is the effect of hypermetropia on the accommodation?

In hypermetropia uncorrected, there is a constant tax or strain on the accommodation to make up for the deficiency of refractive power, causing symptoms of asthenopia, as the accommodation is called upon to do more work than in the emmetropic eye.

What is the effect of myopia on the accommodation.

In myopia there is an overplus of refractive power, on which account the eye is adapted for near vision, and the accommodation is called upon to do much less work than in emmetropia.

What is meant by the term spasm or cramp of the accommodation?

A persistent contraction of the ciliary muscle, which fails to relax, even when there is no need for its contraction.

What is the difference between subnormal accommodation and subnormal range of accommodation?

By subnormal accommodation the writer would understand that the power or amplitude of accommodation was below the normal standard for that particular age.

By subnormal range of accommodation we would understand that the distance between near and far points is less than normal.

What is meant by an "error of refraction" of the human eye?

The refraction of the eye is its optical condition or its action on the rays of light that enter it. When refraction is normal parallel rays are focused on the retina with the accommodation at rest. Any departure from this normal refraction, when the rays are not so focused, is known as an error of refraction.

What kind of ametropic eyes have normal vision or better?

Cases of simple hypermetropia of not too high degree. Here the accommodation is easily able to overcome the defect, and in connection with the contraction of the pupil that is sympathetically produced, the vision is thereby made good, sometimes even sharper than normal.

Why are cases of anisometropia usually hard to fit?

In favorable cases where the difference between the two eyes is not great, the correcting lenses afford good sight in both eyes and comfortable binocular vision is the result. But in many cases the effect of correction is a source of annoyance and confusion.

The effect of the two different lenses on the apparent size of objects must be considered. For instance if one eye is hypermetropic and the other myopic, the convex lens for the first eye causes an apparent increase in the size of the object, while the concave lens for the second eye makes the object appear smaller. While each of these retinal images may be distinct, yet on account of the difference in their size there is difficulty in fusing them, or if fused it is at the expense of strain.

If one crystalline lens has been removed for cataract, on account of the strength of the lens that will be required (+ 10 D. or over), the patient is oftentimes more comfortable if the aphakic eye be left uncorrected, that is provided the other eye has fair vision.

Another source of trouble is the prismatic effect of the different lenses. In converging and looking through the lenses to the inside of the optical center, the convex lens will show a prismatic effect base out and the concave lens a prismatic effect base in. But this disturbance is the more noticeable when looking above or below the optical centers of the lenses than sideways.

The older the patient the more discouraging is the effort to correct anisometropia.

Define three kinds of asthenopia.

Accommodative asthenopia, due to an overtaxing of the accommodation as in hypermetropia.

Muscular asthenopia, due to an overtaxing of the convergence as in myopia.

Retinal asthenopia, where there is hyper-sensitiveness of the retina and suffering is caused by exposure to light.

How may astigmatism of one kind be changed into that of another?

In simple hypermetropic astigmatism, spasm of accommodation transposes the case into one of apparent simple myopic astigmatism with the defect in the meridian at right angles.

Then, too, with the advance of age the addition of the necessary convex lens to correct the presbyopia, changes a case of simple hypermetropic astigmatism and a case of simple myopic astigmatism into one of mixed astigmatism.

How do some people wrongly understand the word squint?

The terms squint and strabismus are used to describe the same condition, but the popular understanding of squint is the act of half closing the lids in the effort to see or to protect the eyes from excessive glare.

What is the difference between tonic and clonic spasm of the ciliary muscle?

A tonic spasm is one that is constant or continuous, while a clonic spasm is intermittent.

What is the difference between concomitant and paralytic strabismus?

In concomitant strabismus, the squinting eye maintains the same relation with the fixing eye and follows it in all of its movements.

In paralytic strabismus, the affected eye is unable to turn in the direction of the paralyzed muscle, and hence cannot follow the movements of the fixing eye.

When would you consider the chances good for the disappearance of squint as the result of wearing glasses?

When the squint is convergent and caused by hypermetropia, when the error is fully corrected, and most important when the glasses are put on at the very commencement of the squint and worn constantly.

Name the different reasons that are held in regard to cause of squint.

These may be intrinsic and extrinsic.

The intrinsic causes are *errors of refraction*, as evidenced by the convergent strabismus of hypermetropia and the divergent strabismus of myopia; and *impaired vision*, as shown by the strabismus that follows amblyopia and opacities of the refracting media.

The extrinsic causes are difference in length or strength or innervation of the muscles; variations in pupillary distance, in shape of eyeball and in divergence of orbits; and impairment of fusion faculty.

What influence, if any, has the correction of errors of refraction on muscular deficiencies?

When esophoria exists with hypermetropia, the correction of the latter by convex lenses has a favorable effect upon the muscular anomaly; but if exophoria is present, the convex lenses would aggravate it.

If exophoria occurs in connection with myopia, the correction of the latter by concave lenses has a favorable effect upon the outward deviation; but if exophoria is present, the concave lenses would make it worse.

Can a myope have a vision of 20/20 or Jaeger 1 without glasses under any circumstances? What would be the visual acuity of a myope of 2 D. and of 6 D.?

Inasmuch as myopia always impairs the acuteness of vision, it is not possible for a myope to have the normal acuity of 20/20, but Jaeger 1 (which refers to the small size reading type) could easily be read if held within the far point, the higher the amount of myopia the more this point is restricted.

In high myopia even with glasses of full correction, it is not always possible to afford a vision of 20/20, on account of the dis-

turbance to the retina from the stretching and the diminishing effect of the strong concave lenses.

The visual acuity of a myope of 2 D. would probably be reduced to 20/200 or one-tenth, and of 6 D. to 6/200 or one-thirtieth.

An emmetrope aged 60 has had his crystalline lens removed for cataract. What glass would you give him for reading and what glass for distant vision? Could he see clearly with either glass at a meter?

For distant vision, the lens needed would be about 10 D. For reading, inasmuch as an aphakic eye is totally devoid of accommodation, the lens must have a focal distance that will correspond with the distance at which the person desires to see. If this is at ten inches, the necessary addition would be + 4 D., or a lens of 14 D. for use at ten inches.

Somewhat of an artificial accommodation can be produced by moving the lens closer to or farther from the eye. As it is moved farther away the effective power of the lens is increased.

If he had a pair for distance and a pair for reading, on account of his loss of accommodation, neither pair would answer at one meter; but according to the rule herein mentioned + 1 D. would have to be added to his distance glasses, which would make + 11 D. for vision at one meter.

A child, aged 12, has vision = 20/30, but with a concave lens of 1 D. it is raised to 20/20. What would you suspect and what tests would you employ to ascertain the true nature of his defect?

We would suspect that this was not myopia at all, but probably false or accommodative myopia due to spasm of accommodation, and that perhaps the real condition of the refraction was hypermetropic. When vision is slightly impaired as in this case, astigmatism is also to be suspected.

The fogging method should be used and will probably show if there is any latent hypermetropia and also if astigmatism is present. Then a careful test with the retinoscope should be made and a comparison of the results obtained from the two methods will reveal the true nature of the defect.

Physiological Optics

Describe in your own language the human eye, giving approximate measurements of the different parts, together with the changes that take place in changing from distant to near vision.

There are three coats, the sclerotic and cornea, choroid, iris and ciliary processes, and the retina. There are three humors, the aqueous, crystalline and vitreous.

In the standard eye the nodal point is situated 7 mm. back of the cornea and 15 mm. in front of the retina. Allowing for the thickness of the coats, the anteroposterior diameter is about 23 mm.

The anterior principal focus is 15 mm. and its posterior principal focus 20 mm., as measured from the two principal points situated about 2 mm. back of the cornea.

The distance between cornea and front of crystalline lens is 3.6 mm.

The distance between cornea and back of crystalline is 7.2 mm.

The distance between cornea and center of rotation is 13.2 mm.

Distance between retina and center of rotation is 9 mm.

In changing the adaptation of the eye from a far point to a near point the following changes take place:

Contraction of the ciliary muscle.

The anterior surface of the lens becomes more convex and approaches the cornea.

The posterior surface of the crystalline increases very slightly in convexity; while the axis of the crystalline increases, the equatorial diameter diminishes. The anterior chamber becomes shallower at center and deeper at periphery. The pupillary edge of iris is pushed forward. The iris usually contracts, producing a smaller pupil.

What is the dioptric apparatus concerned in the static and in the dynamic refraction of the eye?

Refraction of the eye has reference to its action on the rays of light that enter it, whether focusing on or off the retina. If the word refraction is used alone, unqualified by any adjective, it is understood to be the static refraction of the eye—that is, with the accommodation at rest. When the term dynamic refraction is used, we understand that the refractive power of the eye is increased by the action of the accommodation.

In the first condition, the dioptric apparatus concerned would be the cornea, the aqueous humor, the crystalline lens and the vitreous humor, which are known as the refracting media of the eye. In the second condition, the accommodation is brought into play by the action of the ciliary muscle, but this really is not an addition to the dioptric apparatus, but produces an increase in the convexity and refractive power of the crystalline lens, which is one of the media.

Explain why the meter angle is not the same for different persons.

The meter angle is the angle formed by the meeting of the visual line of each eye with the median line when the eyes are directed to an object one meter away. This angle is increased as the object of fixation is brought closer to the eyes.

It is also evident that the size of the meter angle will be affected by the pupillary distance or the distance between the visual lines. The narrower the pupillary distance, the smaller the angle, while the wider the pupillary distance the larger the angle.

What are the essential portions of the eye for carrying out the function of sight?

1. A contractile diaphragm, the iris, to regulate the amount of light admitted to the eye.

2. Certain refracting media, the cornea, aqueous humor, crystalline lens and vitreous humor, which act collectively as a convex lens to focus the rays of light upon the retina and form an image there.

3. A contractile body, the ciliary muscle, which governs the convexity of the crystalline lens and acts as the adjusting

screw of a microscope, to accommodate the eye for vision of short distances.

4. A film or plate, the retina, to receive the images of external objects.

5. Communication with the brain centers by means of the optic nerve, which transmits the impressions formed on the retina.

What would be the effect if the retina was exposed to light with no refracting media in front of it?

Impressions of light would be received, but would afford no idea of form or outline, producing merely the sensation of confused light, amounting simply to the perception of light from darkness.

What is the action of the eye on rays of light entering it? Explain fully how this action is performed and mention the media traversed.

Passing from air (index 1.00) into the cornea (index 1.33) they are very strongly converged; then continuing in the aqueous humor which has about the same index (1.33) and hence may be considered a continuation of the cornea. Passing into the crystalline lens which has a higher index (1.43) and with a convex anterior surface, the rays are still more converged but not as much as on entering the cornea, because the curvature is not so great and *because* the difference between the aqueous (1.33) and the crystalline (1.43) is not as great as the difference between air (1.00) and the cornea (1.33). Continuing then through the more refractive crystalline (1.43) to the less refractive vitreous (1.33), but through a surface which is markedly convex towards the less refractive medium, the rays suffer more convergence and pass on to meet in focus upon the retina.

Explain fully the Helmholtz and the Tscherning theory of accommodation.

The Helmholtz theory of accommodation assumes that, on account of the anterior extremity of the ciliary muscle being

attached to the firm sclero-corneal junction, contraction of the muscle will draw forward the anterior portion of the choroid; as a result the ciliary processes and the suspensory ligament of the lens would also be drawn forward, with a consequent relaxation of the latter.

The crystalline lens is enclosed in a contractile capsule, and in youth when accommodation is most active its substance is soft or semi-fluid. The tendency of such a gelatinous mass is always to approximate the shape of a sphere or globe, according to the laws of physics, because a fixed volume of matter presents its smallest area of external surface in this form, and hence the surface-tension of the mass in connection with the contractibility of the capsule, is constantly trying to reduce this surface area. Therefore under contraction of the ciliary muscle the ligament relaxes and allows the anterior surface of the lens to advance with a decided increase of curvature.

Tscherning argues that accommodation is produced not by relaxation but by increased tension of the suspensory ligament through the agency of the ciliary muscle and that the increase of curvature of the anterior surface of the lens is confined to the portion near the apex of the lens, the curvature diminishing rapidly toward the periphery.

What is meant by the dioptric media of the eye?

The word "dioptric" is derived from the Greek and means to "look through." These are the same as the refracting media of the eye, the cornea, aqueous humor, crystalline lens, and vitreous humor, which act on and refract the rays of light entering the eye so as to form an image on the retina.

What are Purkinje's figures? Draw a diagram illustrating the formation of these figures (a) when the illumination is directed through the sclerotic, (b) when the illumination is directed through the pupillary space.

Purkinje described an entoptic method of observation of the retinal vessels, which was intended to prove that the perceptive faculty for light is located in the outer portions of the cones.

A strong light is focused upon the sclerotic near the cornea and the transmitted light will cast shadows of the intervening blood-vessels on the outer layer of the retina. This perception of one's own blood-vessles is possible because they lie anterior to the principal percipient layer of the retina. The disk cannot be seen because it has no percipient layer, but under favorable circumstances the retina may be seen almost up to the disk, including the macula which is surrounded by capillary loops.

Fig. 33

In a darkened room a candle is held to one side of the eye at an angle of about 30 degrees with visual line on one side, and if the observer's eye be at an equal angle on the other side, there can be seen three distinct reflected images of the candle flame.

1. A bright virtual image of the flame reflected from the cornea acting as a convex mirror.

2. A virtual image of the flame reflected from the anterior surface of the crystalline lens, also acting as a convex mirror. This image is larger, less distinct and not so noticeable as the first.

3. A bright but small real image reflected from the posterior surface of the crystalline, acting as a concave mirror.

The first and second images are upright and the third is inverted.

The eye under observation is now made to change its point of sight from a distant to a near object; in other words, to accommodate, when it will be seen that the second image which it reflected from the anterior surface of the crystalline becomes smaller and clearer, and moves forward and toward the center of the pupil; thus proving that this anterior surface of the crystalline becomes more convex. Images 1 and 3 are not changed, thus proving that the other surfaces are not affected by accommodation.

What is the axis of vision?

This is the line which joins the object with the fovea centralis; it is also known as the visual line.

The eye is said to be chromatic, and yet this condition is not usually manifest. How can its existence be shown?

By the use of a cobalt blue glass while looking at a light. This lens allows both blue and red light to pass through it, the former being most refracted and the latter least.

What are the nodal points of the eye?

The nodal point is located at the center of curvature of the eye, or at its optical center, and is the point through which rays pass without deviation. It may be said to coincide with the apex of the posterior surface of the crystalline lens.

Every lens, strictly speaking, has two nodal points, but in thin lenses the deviation of the secondary rays is so slight that for all practical purposes only one nodal point is recognized.

The first nodal point lies 7.09 mm. behind the anterior surface of the cornea, and the second nodal point 7.46 mm. behind. The interval between the two nodal points is so small that they can be regarded as one, and its distance is given as 7.2 mm. behind the cornea. The angle which an object subtends at the nodal point governs the size of the retinal image.

How is accommodation accomplished?

By means of the ciliary muscle acting upon the crystalline lens in such a way as to increase its convexity. There are two theories of accommodation as promulgated by Helmholtz and Tscherning. According to the first the lens tends to assume a spherical shape when allowed, which is accomplished by the action of the ciliary muscle on the fibers of the zonula, so as to permit the lens to assume a more spherical shape. According to the second the periphery of the lens is flattened, with the result of causing a bulging at the center.

What is the optic axis of the eye?

An imaginary line that passes through the apex of the cornea and the center of the crystalline lens to a point on the retina at the center of the fundus.

Suppose for any reason an emmetropic eye should become myopic, what would be the change in the size of the apparent size of objects?

The size of the retinal image is governed by the distance between the nodal point and the retina, that is, the distance the rays diverging from the nodal point must travel before reaching the retina.

Inasmuch as this distance increases in the elongated eye of axial myopia, it follows that there will be an increase in the apparent size of objects.

What is the relation of the dioptric system of the eye to the retina in each of the following cases: emmetropia, myopia, hyperopia, astigmia?

In emmetropia the dioptric system is of such power as to focus parallel rays upon the retina with the accommodation quiescent. In myopia the dioptric system shows an excess of power, causing parallel rays to focus in front of the retina. In hypermetropia there is a deficiency of refractive power, allowing the focus of parallel rays to go behind the retina.

In simple hypermetropic astigmatism the dioptric power of one meridian is just right, and of the other meridian deficient.

In simple myopic astigmatism, one meridian just right and the other meridian in excess.

In compound hypermetropic astigmatism, both meridians deficient but one more so than the other.

In compound myopic astigmatism, both meridians in excess but one more so than the other.

In mixed astigmatism one meridian deficient and the other in excess.

What position does an image on the retina have relative to the object?

The reproduction on the retina of the object seen is in the form of an inverted image, and this image and the object are conjugate to each other.

What is the dioptric value of 1 mm. variation in the distance of the image formed in an eye with the ciliary at rest?

About 3 D. to be added if the optic axis is lengthened, and subtracted if the axis is diminished.

Estimating roughly, what would be the increase in the power of an emmetropic eye if the radius of the cornea were 1 mm. more or less than is actually the case?

In curvature ametropia each millimeter of lengthening or shortening of the radius of curvature is equivalent to about 6 D.

In a certain eye the power of the anterior surface of the cornea is 42 D., while the total dioptric power of the eye is 52 D. What will be the dioptric power of the eye if this head is immersed in water, the refractive index of the cornea being considered the same as water?

Refraction occurs when light passes from one medium to another of different density, as long as it remains in the same medium there can be no refraction. In this case where the eye is immersed in water and where the cornea and the water have the same refractive index, light, in passing from the water into the cornea is practically traveling in the same medium, and

hence there will be no refraction. The refractive power of the cornea being thus destroyed, there is a loss of 42 D. and the dioptric power of the eye is thereby reduced to 10 D. This explains why a swimmer who opens his eyes under the water is so intensely hypermetropic that he is unable to see objects distinctly.

What is chromatic aberration, and how is it detected in the human eye?

Inasmuch as the degree of refraction by a prism varies with the wave length, therefore refraction by spherical surfaces causes red to deviate the least and violet the most, and as a result the various colors do not focus at the same point. This is known as *chromatic aberration.*

When the eye accommodates for one set of rays, it is out of focus for another, which tends to cause a fringe of colors around the image. This defect in the normal eye is so slight that the brain fails to take cognizance of it and it is not noticeable in ordinary vision.

That it does exist in the eye, however, can be proven by the use of a cobalt lens, which is placed before the eye while the patient is asked to look at a luminous point. This substance has the property of intercepting all but the red and blue rays. The patient will see an image with a red center clearly defined, and a periphery of blue, ill defined, for the reason that the eye more readily accommodates itself for the red rays, making their focal point distinct. The blue rays being more highly refracted come to a sooner focus, cross and diverge, giving rise to diffusion circles.

If a concave lens be added to the cobalt, the blue rays will be focused on the retina while the red will now fall in diffusion circles, causing an image with a blue and distinct center and a red and diffused periphery.

Name the different ametropic conditions of the eye. Explain each condition, giving its correction by lenses.

Emmetropia is an eye in measure, when with a passive accommodation parallel rays are accurately focused upon the

retina; *ametropia* is a departure from this condition, showing itself in *axial ametropia* (hypermetropia and myopia) and *curvature ametropia* (astigmatism). Hypermetropia and myopia may also be due to a diminution or increase of curvature of the cornea or crystalline. Presbyopia is not included, because it is a physiological change that comes on with the advance of age.

Hypermetropia: On account of shortness of the anteroposterior axis of the eyeball, or deficiency of refractive power in cornea and lens, parallel rays strike the retina before uniting in a focus, making the imaginary focus behind the retina.

In order that light may focus upon the retina of a hypermetropic eye the rays must be convergent instead of parallel. There are two ways in which this can be done.

First. By the use of the accommodation, which the hypermetrope does unconsciously, but as this is an unnatural use of the accommodation, headache and asthenopia are likely to result.

Second. Artificially by the use of a convex lens, which converges the rays before entering the eye.

Myopia: On account of the length of the anteroposterior axis of the eyeball, or excess of refractive power in the crystalline lens and cornea, parallel rays are brought to a focus too soon and meet in front of the retina.

In order that the focus may be thrown farther back to the retina, the rays must be divergent instead of parallel.

The eye possesses no power of its own to accomplish this, but it can be done artificially by means of a concave lens which diverges the rays before entering the eye.

Inasmuch as the rays from near objects are divergent, they can be focussed on the retina of the myopic eye, hence near vision is clear while distant vision is blurred.

Astigmatism. In this error there is a difference in the curvature of the cornea in its several meridians, those of greatest and least refractive power being at right angles to each other and known as the principal meridians.

The rays passing through the vertical meridian which is normal, are focussed upon the retina; while the rays passing through the horizontal meridian which shows an excess in curvature, are brought to a focus in front of the retina. This represents simple myopic astigmatism, and is corrected by a concave cylin-

der, which diverges the rays passing through the horizontal meridian and throws them back to the retina.

Astigmatism may be *simple*, where one meridian is emmetropic and the other hypermetropic or myopic; *compound* where both meridians are defective, but one more so than the other; *mixed*, where one meridian is myopic and the other hypermetropic.

What determines the visual acuity of an eye? What constitutes normal vision? Is normal vision always present when refractive conditions are emmetropic?

The acuteness of vision is determined by the smallest distance between two points at which they can be separately distinguished. It has been found that the minimum visual angle for seeing points should be about one minute.

Snellen's test types, which are in constant use for determining the visual acuity, are constructed of such sizes that the whole letter will subtend an angle of five minutes, and each limb of the letter (upon which its visibility depends) an angle of one minute.

The No. 20 line when placed at a distance of twenty feet will subtend these angles, and hence when a person can name these letters at this distance, we say he possesses normal visual acuity.

The eye may be emmetropic and a well defined image formed upon the retina at the macula, but if this impression is not conveyed to the brain by reason of any failure of the function of the optic nerve, or of the retina or of the centers in the brain, there could be no resulting vision.

What is the cause of presbyopia? State the functional disturbances in presbyopia.

The cause of presbyopia is a gradual lessening of the power of accommodation. This is a physiological condition, and is dependent upon a diminished elasticity of the crystalline lens and a loss of contractibility of the ciliary muscle. When the amplitude of accommodation falls below 4.50 D. or 5 D. there is not sufficient reserve to allow of comfortable vision at reading distance, and artificial assistance is called for.

The loss of accommodation in presbyopia destroys the rela-

tion that had in earlier years existed between the functions of accommodation and convergence.

Is the refraction of the eye affected by spasm of the ciliary muscle? What is (a) tonic spasm of accommodation, (b) clonic spasm of accommodation?

Spasm of the ciliary muscle causes parallel rays of light to come to an earlier focus, thus simulating myopia. Even in hypermetropia there may be an apparent myopia, caused by the action of the muscle going beyond the limit and producing an overcorrection.

It is to be understood that the refraction of the eye is not actually altered; the change is only apparent, not real.

A tonic spasm is one that is persistent and continuous, while a clonic spasm is intermittent.

What causes diplopia? Define and explain three kinds of diplopia.

When the image is focused upon portions of the two retinæ that do not correspond, the brain is unable to fuse them, and double vision or diplopia results. Diplopia may be produced artificially by placing a prism before one eye, which deflects the rays from the macula of that eye, for which purpose the prism must not be so weak as to be easily overcome by a contraction of the muscles.

Homonymous diplopia is that form in which the right image is seen by the right eye and the left image by the left eye.

It is caused by an inward deviation of the eye, as in esophoria. In such a case the ray of light impinges upon the retina at the inner side of the macula, and is referred in the opposite direction, or outwardly according to the law of projection.

In *heteronymous diplopia*, the diplopia is crossed, the right image belonging to the left eye and the left image to the right eye. This occurs in those cases of muscular imbalance where there is an outward deviation of the eye; under such circumstances the ray of light strikes the retina at the outer side of the macula, and is referred in the opposite direction, that is inwardly according to the law of projection and the diplopia thus produced is crossed.

Diplopia may also be *vertical*, due to hyperphoria or hypertropia.

In right hyperphoria, the visual line of the right eye tends upwards in which case the ray of light entering this eye strikes the retina at a point above the macula and is referred in the opposite direction or downward. Hence the lower image would belong to the right eye and the upper image to the left.

In left hyperphoria the visual line of the left eye tends above that of the right, under which circumstances the ray of light impinges upon the retina at a point above the macula (in the left eye) and is referred in the opposite direction or downward. In this form of vertical diplopia the lower image would belong to the left eye and the upper to the right.

Which are the meridians of greatest and least corneal curvature when the concentric circles of Placido's disk appear reflected as horizontal ellipses?

The greater the curvature the closer the lines of the circle would be brought together; therefore in this case where the upper and lower borders of the circle are approximated, we would say the vertical was the meridian of greatest curvature, and the horizontal the meridian of least curvature.

What is dynamic refraction?

The refraction of the eye is its action while in a static state on the light that enters it and dynamic refraction is when the action of the ciliary muscle is added to that of the refraction media.

The far point with a plus 3.50 lens in place is at 50 cm.; and the same eye with a plus 1.5 lens in front of it has the near point at 20 cm. What is the refractive condition and what is the amplitude of accommodation?

If the far point with a + 3.50 D. lens is located at 50 cm., there would be presumably an artificial myopia of 2 D., which would mean an overcorrection of that amount. Therefore, + 1.50

D. would be the lens to make the eye emmetropic showing a hypermetropia of that amount.

A near point of 20 cm. would indicate an amplitude of accommodation of 5 D. but if this was obtained with the assistance of the correcting lens of + 1.50 then the amplitude of accommodation of the unaided eye would be 3.50 D.

In presbyopia is it not a fact that the radiating fibers of the ciliary muscles have lost a part of their elasticity; they are not so elastic as when young? Would this not be a good definition of presbyopia?

The approach of presbyopia is caused by the lessening of accommodative power on account of the inability of the crystalline lens to continue to assume the increased convexity which was so easily possible in earlier years. So far all are agreed; now then as to the cause.

While it is doubtless true that the radiating fibers of the ciliary muscle lose part of their elasticity this does not enter into the question, as it is the circular or sphincter fibers that are actively concerned in the function of accommodation.

Ordinarily we say that the failure of accommodation that underlies presbyopia is due to a loss of contractility of the ciliary muscle and of elasticity of the crystalline lens; but the probabilities are that the latter is the most important factor. Doubtless the muscle weakens somewhat, but it is the increasing sclerosis of the crystalline which can no longer respond to the action of the ciliary muscle, that is mainly responsible for the condition known as presbyopia.

What is the size of the retinal image of an object 9 cm. high and 1.5 meters distant from the eye of a hypermetrope of 3 D.?

The size of the retinal image varies in different eyes on account of the varying distance of the nodal point from the retina, that is, on the distance which the axial rays have diverged from each other after leaving the nodal point and when they reach the retina. The farther these rays have to travel before reaching the retina the more they are separated and, therefore, the greater the retinal area occupied by the image. This explains why in the

elongated eye of myopia objects seem larger and in the flattened eye of hypermetropia things are seen smaller.

In addition to its distance from the nodal point the size of the retinal image depends upon the size of the object and its distance from the eye.

The size of the retinal image bears the same relation to the size of the object itself as the distance between the nodal point and the retina bears to the distance between the nodal point and the object.

In an emmetropic eye the distance of the retina from the nodal point is 15 mm., but in a hypermetropia of 3 D. that distance is reduced to 14 mm.

The problem may be expressed as follows. The size of the image is to size of object as image distance is to object distance. Let x represent the size of the retinal image and substituting figures we have

$$x : 90 \text{ mm.} :: 14 \text{ mm.} : 1500 \text{ mm.}$$

$$\text{then } x = \frac{90 \times 14}{1500} = 0.84 \text{ mm.}$$

Multiply size of object (9 cm.) by image distance (14 mm.) and divide by object distance (1.5 meters) and the result is 0.84 mm. as the size of the retinal image.

What muscles are brought into play in convergence to a point 80 inches and 4 inches away?

In convergence at 80 inches the internal recti muscles are brought into action; at 4 inches they are supplemented by the superior and inferior recti.

Also in simple myopic astigmatism complicated with presbyopia, while the concave cylinder will serve for distance, a convex cylinder at right angles will be needed for reading.

What change must be made with incident parallel rays of light so as to have them focus on the retina when it is situated beyond the principal focus of the dioptric system?

If the retina is situated beyond the principal focus of the dioptric system, or in other words if parallel rays come to a

focus too soon (as is the case in myopia) they must be made divergent before entering the eye so as to throw the focus further back upon the retina which can be accomplished by means of a concave lens of the proper strength.

Explain the reason for the improvement in vision obtained by the pinhole disk.

In the several forms of ametropia parallel rays of light cannot focus upon the retina and as a result the acuteness of vision is impaired. In hypermetropia the rays reach the retina before coming to a focus, whereas in myopia they meet in front of the retina and cross and diverge; in both cases the retina receives circles of diffusion. The pinhole disk cuts off the peripheral rays and allows only the more central ones to pass, and in this way reduces the amount of diffusion and affords the more perfect image of the central ray which passes unrefracted. Of course, the illumination is reduced by cutting off so much light, but this is more than compensated for by the improvement in the sharpness of the retinal image.

Explain the method applied to ascertain the powers of abduction and adduction, supraduction and infraduction.

The duction tests consist in applying prisms as strong as can be borne with apices over the muscle it is desired to measure.

The strongest prisms *bases in* which can be overcome and with which single vision of a light can be maintained, will represent the power of *abduction.*

The strongest prisms *bases out* which can be overcome will represent the power of *adduction.*

The strongest prisms *bases down* for *supraduction*, and *bases up* for *infraduction.*

The eye turns toward the apex of the prism, and when the limit of its duction power is exceeded the light becomes double.

Why is it necessary to change occasionally the focus of glasses for close range after the patient has passed the age of forty?

Such persons wear glasses for the correction of their presbyopia, which is an error of accommodation, and depends upon the lessened power of this function due to the changes which age brings on. As these changes are progressive the amplitude of accommodation gradually diminishes until it is finally lost altogether. This necessitates a change of glasses, increasing their strength about .50 D. every two and one-half years.

What are the effects of the extrinsic muscles on the relation of the visual lines of the two eyes?

The effect of the extraocular muscles is such as to keep the optic axes of the two eyes in a proper relation to each other in all the ordinary movements of the eyes that binocular vision shall always be present no matter in which direction the eyes may find it necessary to turn.

What is the posterior principal focus of the eye?

It is the focus for parallel rays that enter the eye, and in the emmetropic eye is located at the retina; when such is the case the eye is adapted to receive a clear image of a distant object.

In hypermetropia with the accommodation at rest, the principal focus of the eye is located behind the retina, as a result of which the retinal image will be blurred. In myopia the principal focus of the eye lies in front of the retina, and again the image on the retina will be blurred.

What will be the height of the image of a 6-foot man on the retina of an emmetropic eye if the man is 100 feet away?

The angle formed at the nodal point governs the size of the image on the retina, or we may express it in this way, that it depends upon the distance between the nodal point and the retina. The rays meet at the nodal point and then they begin to diverge. The farther away the retina, the more these rays diverge, and therefore the greater the area on the retina occupied by the image. This explains why in myopia, where the retina is farther from the nodal point the image is larger, and in hypermetropia where the retina is nearer to the nodal point, the image is smaller.

In calculating the size of the retinal image it is to be remembered that its size bears the same relation to the size of the object as the distance of the retina from the nodal point (which means the distance of the image from the nodal point) bears to the distance of the object from the nodal point, which may be expressed in the following proportion:

Size image : Size object :: Distance image : Distance object.

Allowing 15 mm. as the estimated distance of the nodal point from the retina and substituting figures in this case, we have:

$$x : \frac{\text{6 feet}}{\text{or 1800 mm.}} :: \text{15 mm.} : \frac{\text{100 feet}}{\text{or 30,000 mm.}}$$

or $x = 27/30$ of a millimeter, which is the height of the retinal image.

What glasses must be prescribed for those who no longer possess the function of accommodation?

This question no doubt has reference to old age, in which, according to natural laws, the power of accommodation has been entirely lost.

In these cases there is usually more or less of acquired hypermetropia, due to the lessening of refractive power as a result of the senile changes. This will call for correction and in addition another pair of glasses must be given for reading, about 2.50 D. or 3 D. stronger than the distance pair; or preferably a pair of bifocals.

In eyes which are strictly emmetropic and in which the function of accommodation has been lost, the glass that is given must correspond with the desired reading distance; if at 13 inches, 3 D.; if at 10 inches, 4 D., and so on.

When is hypermetropia said to be absolute?

When it cannot be neutralized by the accommodation, either because the defect is of too high degree or because the accommodative power has been lost, as in old age. Under such conditions vision is impaired at all distances, but especially near vision.

When is hypermetropia said to be facultative?

When it can be neutralized by the accommodation. His vision is good either with or without a convex lens. This is the condition usually found in early life.

What is the difference between regular and irregular astigmatism?

Regular astigmatism is due to a toric shape of cornea or crystalline, the curvature being regular from the minimum to the maximum meridians, and the defect can be readily corrected by cylindrical lenses.

Irregular astigmatism is caused by unevenness of the surface of the cornea, there being a difference in refraction in different parts of the same meridian. As a result of this distortion of the cornea, an imperfect retinal image is formed and cylindrical lenses are of little value.

What is the difference in meaning between esophoria and esotropia?

Esophoria signifies a tendency to inward deviation, esotropia an actual turning of the eye inwards.

Which will produce the poorest visual acuity, an error of 2 D. spherical or 2 D. astigmatically?

If the error is myopic, it is probable that the spherical error will impair vision the most. But if the error is hypermetropic of not too high degree it is probable the accommodation can more completely overcome the spherical error, and hence in this case it is likely that the astigmatic error will produce the poorest vision.

In measuring the amplitude of accommodation with a reading chart why is the test not exact?

Because for short distances the type is too large and because a person becomes familiar with certain words by their appearance as to the number of letters composing them and the shape of

such letters, so that he is able to make a very good guess at words even when he does not see the letters plainly.

What is hyperphoria and what is the position of the correcting prisms?

Hyperphoria is the term used to indicate a tendency of the visual line of one eye to place itself above that of the other. This upward tendency may affect either eye, and hence we have right hyperphoria or left hyperphoria.

The position of the correcting prism is base down over the hyperphoric eye, or base up over the other eye, or divided between the two eyes in these positions.

When the refraction of the two eyes differs what term is applied to the condition?

Anisometropia is the usual term, although the word antimetropia is also used. It is seldom we find the two eyes exactly alike, but the term is applied only when the difference is great enough to receive consideration.

Anisometropia is usually a congenital condition, but it may also be due to the natural progress of a myopia, to operation or injury, and to changes in corneal curvature.

If the punctum proximum in emmetropia is at 33 cm. when the eyes are being assisted by + 1.50 D. lenses, what is the amplitude of accommodation and what lenses should be prescribed for reading at 33 cm., so as to keep one-third of the accommodation in reserve?

A near point of 33 cm. represents an amplitude of accommodation of 3 D. and as this is accomplished by the assistance of a + 1.50 D. lens the natural amplitude of accommodation would be 1.50 D.

In order to read at 33 cm. 3 D. of power is required, and in order that one-third of this person's accommodation should be kept in reserve, he can use only 1 D. of his own accommodation and the balance must be supplied by a + 2 D. lens.

When the eye turns up and in, by what muscles is it controlled?

Superior rectus and internal rectus, the upward movement being probably assisted by the inferior oblique.

In the static eye in the case of an emmetrope, what will be the effect on the retinal image of wearing a + 1 D. cylinder, axis 180°?

To distort the image, elongating it in the vertical meridian or at right angles to axis of cylinder.

What is the condition of the muscles of the eyes in each of the following cases: Orthophoria, esophoria, exophoria, hyperphoria?

Orthophoria, muscles properly balanced; esophoria, tendency to overconvergence; exophoria, tendency to over-divergence; hyperphoria, a tendency of one visual line above the other.

In esophoria the correcting prism is placed base out, in exophoria base in, and hyperphoria base down over the hyperphoric eye.

What is spasm of the ciliary muscle?

An involuntary cramp or contraction of the ciliary muscle. This is the term applied to an overaction of the accommodation, occurring especially in young people in the effort to overcome a condition of hypermetropia or hypermetropic astigmatism and makes the eye apparently and subjectively myopic, thus leading the inexperienced optometrist sometimes into the error of prescribing concave glasses.

It is more apt to occur in patients whose nervous system is broken down and oftentimes in those with a relatively weak accommodation.

The usual symptoms are photophobia, lachrymation, pain, contracted pupils and congestion of the eye, together with the appearance of myopia.

How is spasm cured?

The first step in the treatment is the removal of the cause if it can be ascertained, as the correction of any existing hyperme-

tropia or astigmatism. Or convex lenses for fogging to induce relaxation of the accommodation, a weaker pair for distance and stronger for reading. Rest of the eyes and temporary abstinence from reading and sewing should be advised.

What is diplopia and what is the explanation?

Diplopia is double vision, two images being seen instead of one, and is due to the fact that the images are not formed on corresponding parts of the two retinæ.

What is the character of the difference in direction of the eyes if diplopia is homonymous?

Esophoria, or inward deviation.

What is monocular diplopia and what is its explanation?

Multiple vision in one eye, usually due to a slight difference in the index of refraction of the several main segments of the crystalline lens, each of which gives rise to a separate retinal image.

In emmetropia these images are so close that they are fused into one, but in ametropia, where the retina is not at the position of the average focus, vision is multiple.

What is heterophoria and how does it differ from diplopia?

Heterophoria is the term used to include all those conditions in which there is a tendency to depart from the normal muscular balance, which nature is able to compensate for and keep latent, but which is demonstrable by the usual tests.

Diplopia means double vision, and is produced by and is a symptom of *heterotropia*, a term used to include all those conditions in which nature is unequal to the task of maintaining its desire for single vision.

What is anisometropia?

This term is applied to that condition of the eyes where the refraction is unequal. In a restricted sense of the word we

seldom find two eyes exactly alike, but the term is used only when the difference is great enough to be taken into account. The usual condition is where the character of the refraction is the same in both eyes, varying only in degree. Where the character of the refraction varies in the two eyes, that is one eye hypermetropic and the other myopic, the term antimetropia is sometimes used.

What conditions produce diplopia?

Diplopia occurs when the visual axes are directed so that the image of the object does not fall upon identical parts of both retinæ. Any disturbance of the extra-ocular muscle balance, as in heterotropia, or even in heterophoria may cause this condition, and sometimes it is due to faulty innervation.

Which surface of the cornea has the greater refractive power, and why?

The refracting power of the cornea lies chiefly in its anterior surface. The effect of the posterior surface is neutralized by being in contact with the aqueous humor which has the same index of refraction, and, therefore, the aqueous may be considered as a continuation of the cornea.

How can the degree of convergence be determined for any given working distance, and for any given pupillary distance?

The rule is to divide the pupillary distance by the unit of displacing power at the given working distance.

If we take a working distance of 13 inches (which is one-third of a meter) the displacement would be 3.33 mm., based on the unit or standard of displacement of 10 mm. for each meter of distance. We will assume the pupillary distance is 2½ inches, which is equivalent to 64 mm. Then the number of degrees of convergence in a patient with the pupillary and working distances mentioned above is found by dividing 3.33 into 64, and the result is 19.21 degrees of convergence.

What is the dioptric power of the anterior surface of the cornea, and what is its power as a convex mirror?

In order to find the refractive power of the cornea we divide its index of refraction, less unity, into its radius of curvature, as follows:

$$\frac{8 \text{ mm.}}{(1.33-1)} = 24 \text{ mm.}$$

24 mm. is its focal length and we find its refractive or dioptric power by dividing this into 1000 mm., and the result is 41 D.

Assuming, as we have done in the above example, that the radius of curvature is 8 mm. and as the focus of a mirror is one-half its radius, its focal length as a mirror is 4 mm., and its power is found by dividing this into 1000 mm., the result being 250 D.

What is difference between binocular vision and fusion?

They mostly convey the same meaning; but a person with binocular vision whose fusion sense is but feebly developed will under unfavorable circumstances abandon the effort and drop into monocular vision. While another person whose fusion sense is well developed will have such an intense tendency to binocular vision that nothing will cause him to abandon it.

What is the name given to that part of the retina in which visual acuity is the sharpest?

Macula lutea, or yellow spot in general and fovea centralis in particular.

What would be the change in the refraction of the cornea if its radius of curvature should be changed about 1 mm.?

It depends upon whether the change of radius was in the direction of an increase or a decrease. If the radius of curvature was increased 1 mm. there would be a decrease in refractive power of approximately 5 D. Whereas, if the radius of curvature of the cornea was lessened 1 mm. there would be an increase of refractive power of nearly 7 D.

What would be the change in the dioptric power of the crystalline lens if the radius of curvature should be changed 1 mm.?

Here the two surfaces of the crystalline must be taken into account in considering its dioptric power.

If the anterior surface showed an increase in radius of 1 mm. there would be a loss in power of 1 D. If this surface showed a decrease in radius of 1 mm. there would be an increase in refractive power of 1 D.

If the posterior surface showed an increase in radius of 1 mm. there would be a loss of power of 2 D. If this surface showed a decrease of 1 mm. there would be an increase in refractive power of 3 D.

If the radius of the two surfaces was changed 1 mm. the resultant change in dioptric power can be figured from above.

The distance between the centers of the two eyes when they are looking into distance is 62 mm. If the glasses used are placed about 12 mm. in front of the cornea and the object of regard is at a distance of 20 inches, what must be the pupillary distance of the glasses?

An optical writer figures it as follows: The centers of rotation are 13 mm. back of cornea, therefore, the distance from these centers to the lenses would be 25 mm., or 1 inch. Then the lenses would be 19 inches from the object, and the p. d. of the glasses would be 19/20 of 62 mm. or 59 mm.

At what ages does the accommodation of the eye being to decrease?

At ten years, continuing gradually to decrease until it is entirely lost in old age.

What is the difference in the function of the blind spot and of the yellow spot?

The blind spot is at the entrance of the optic nerve, and as it is insensible to light it cannot be said to have any function.

The function of the retina is to receive the images of external objects and transmit the impressions to the brain. The yellow spot is that part of the retina that is most highly developed for this purpose.

Why is the pupillary distance less for near glasses than for distant ones?

Because the eyes turn in in response to the increased convergence that is necessary to maintain binocular vision at near points, and in so doing the pupillary distance is necessarily lessened.

What is meant by the term function of convergence?

When the word convergence is used some students at once think of the bringing to a focus of parallel rays of light, as by action of a convex lens; but in this case the word refers to the function that has control of the direction of the visual axes of the two eyes, so that they shall both meet at the point of fixation, which is at some finite distance.

What is the difference in the direction of the line of sight and of the optic axis of the eye?

Inasmuch as the fovea centralis does not lie exactly upon the optic axis it follows that the optic axis and the visual axis, which joins the fovea with the point looked at, do not coincide. The angle formed at the nodal point where the optic and visual axes cross has been termed the angle alpha, or angle gamma. Its size is variable, in emmetropia usually not more than five degrees, increasing in hypermetropia and decreasing in myopia.

What is the fundamental difference between the two leading theories of accommodation?

According to the Helmholtz theory the contraction of the ciliary muscle causes a relaxation of the capsule of the crystalline lens and allows it to assume a greater convexity through its natural desire to become so. According to the Tscherning theory the contraction of the ciliary muscle flattens the periphery of the crystalline and causes it to become more bulging at the center. Under either condition there is an increase in the dioptric power of the lens.

What is the total length of the human eye and the dioptric value when in a static condition?

Approximately 24 mm. and 58 D. respectively.

What is meant by the term visual acuity?

Visual acuity has reference to the image formed on the retina and thence transferred to the brain. It is the sharpness of sight and is determined at a distance of twenty feet or more with accommodation at rest, and depends upon the smallest retinal image, the form of which can be distinguished by the brain. It is expressed by a fraction, the numerator of which is the distance of the letters and the denominator the size letters that can be named. Visual acuity equals 20/20 means that the letters are 20 feet away and the patient can read the No. 20 line.

With eyes in the primary position, what prism is needed to produce binocular vision for a small object at a distance of one meter from the eye?

If we assume the pupillary distance to be 60 mm. then the visual lines will be the same distance apart. At a distance of one meter a prism of one degree will show a displacing power of 10 mm.; therefore, to overcome the separation of 60 mm. at one meter distance a prism of 6° would be required, or a 3° prism over each eye.

What is the relation between diopters of accommodation and meter angles of convergence?

There is a close and constant relation between the two. At a distance of one meter there is one diopter of accommodation and one meter angle of convergence, and for all distances the same proportion should hold good—that is, one meter angle of convergence for each diopter of accommodation.

How can it be proved that the human eye is not achromatic?

It is not possible for red and violet rays (from the two ends of the spectrum) to be focused on the retina at the same time.

But these colors possess little luminosity as compared with yellow, on which vision chiefly depends, and hence the fact that they are out of focus at the retina is not of great importance, nor does chromatism manifest itself in ordinary vision in approximately normal eyes. Its effects are more noticeable in ametropes, but its existence in any eye can be proved by looking at a light through a cobalt-blue glass, which blocks the central part of the spectrum and allows mainly the red and blue light to pass through it, the two extremes of the spectrum. The patient may see a red center with a blue border, or a blue center with a red border, depending on which color focuses nearest the retina.

What causes the amplitude of accommodation to decrease?

Principally due to loss of elasticity or increase in firmness of the crystalline lens, with perhaps some loss in contractibility of the ciliary muscle, which conditions are the natural accompaniments of age.

What is meant by positive and negative convergence?

Positive convergence is the turning of the eyes inward from parallelism, as in the act of convergence, and negative convergence is turning the eyes outward from parallelism, as in the act of divergence.

In what units of measurement is the amplitude of convergence expressed, and describe the unit?

In meter angles, the unit of which is the angle formed by the visual lines of the two eyes meeting at a point one meter away.

What is meant by the static refraction of the eye?

The action of the refracting media of the eye on light uninfluenced by the accommodation.

What is meant by the term dynamic refraction of the eye?

The action of the refracting media of the eye augmented by the power of accommodation.

Describe two ways of getting the amplitude of the accommodation.

The usual way is by means of the small test types and noting the closest point at which they can be read.

Or a card may be used in which two small holes are pricked by a pin, the distance between which must be less than the diameter of the pupil. The card is held close in front of the eye and a small needle viewed through the pinholes. When the needle is brought too close it appears blurred and double. The closest point at which it remains clear and single represents the amplitude of accommodation.

By what test may the effect of a refractive error in the eye be so cut down that vision will be improved, and what is the explanation of its action?

By the pinhole test, which cuts off so many rays and nullifies the refractive power of the eye, allowing the image to be formed by the action of the pinhole alone, through which a ray from each point of the object passes, and as the rays pass they cross and form an inverted image.

What is the nature of the retinal image as to exactness of focus in emmetropia, in hypermetropia, in myopia and in astigmatism?

In emmetropia the retinal image is ideally perfect. In hypermetropia, if not of too high a degree, it is approximately distinct, being made so by the accommodation; if the accommodation is not used the image would be blurred. In myopia it is indistinct except when the object is placed at the far point of the eye. In astigmatism the retinal image is in the shape of a line instead of a point, but in low degrees of hypermetropic astigmatism the ciliary muscle is usually able to make vision clear.

When the eyes are first fixed on an object at close range and then on some object further away what ocular changes occur?

The ciliary muscles relax so as to cause the crystalline to become less convex and thus adapt the eye for distant vision; there is also a lessening of convergence so as to allow the visual axes to meet at the greater distance desired.

When the far point and near point are both positive or real what is the space between them called?

The range of accommodation.

With a + 1 D. lens placed in front of a certain eye the near point is at 20 inches. The test shows that the static refraction of the eye is 2.50 D. hypermetropic. What is the amplitude of accommodation?

If the near point is located at 20 inches by the aid of a + 1 D. lens then the unassisted eye would show a near point of 40 inches, which is equivalent to 1 D. of accommodation.

However, as the 2.50 D. of hypermetropia must first be neutralized by the accommodation before near vision is attempted, the amplitude of accommodation must be 3.50 D.

What is the size of the object 5 meters away that forms on the retina of a hypermetrope of 3 D. an image 5 mm. in size?

The size of the retinal image bears the same relation to the size of the object as the distance from the nodal point to the retina bears to the distance from the nodal point to the object.

In the emmetropic eye the distance between the nodal point and the retina is estimated at 15 mm. But in a hypermetrope of 3 D., as in this case, this distance is reduced to 14 mm.

Then we have the following proportion: the size of the object is to the size of the image as the distance of the object is to the distance of the image. Substituting the figures:

$$x : 5 \text{ mm.} :: 5{,}000 \text{ mm.} : 14 \text{ mm.}$$
$$14\,x = 25{,}000 \text{ mm.}$$
$$x = 1{,}785 \text{ mm.}$$

which is the size of the object.

How does the function of the eye differ in dynamic and static refraction?

Static refraction with the fixation at 20 feet or more is considered a passive condition, while dynamic refraction with the fixation at the reading or working distance is an active condition with the ciliary muscle at work.

How many diopters of accommodation are required in an emmetropic eye to see clearly an object at 20 feet?

In the practice of optometry a distance of 20 feet is selected for making the visual tests, on the assumption that rays proceeding from this distance are practically parallel. But this is not strictly correct, because rays at this distance have a divergence of 1/240 of an inch, and would require a + .17 D. (one-sixth of a diopter) to make them parallel, or the use of an equal amount of accommodation.

How do we measure the amplitude of accommodation, and why is it expressed in diopters?

We measure the amplitude of accommodation by finding the position of the near point, which is the closest possible point one can see with the strongest effort of accommodation, and it is equivalent to a convex lens (expressed in diopters) of such strength as will give to rays proceeding from this near point, a direction as if they came from distance, or in other words makes them parallel.

How is the size of the image of an object that is defined by the minimum visual angle at 6 meters distance determined when the nodal point of the eye is 15 mm. in front of the retina? What is the size of the objects?

The size of the retinal image of an object bears the same relation to the size of the object itself as the distance between the nodal point and the retina bears to the distance between the nodal point and the object.

As the nodal point in the emmetropic eye is usually estimated to be 15 mm. from the retina, the proportion is as follows: As the distance of the object is to the size of the object, so is 15 mm. to the size of the retinal image.

Or in other words, the size of the object is multiplied by 15, and the result divided by the distance of the object, in order to find the size of the retinal image.

What is the difference in the focusing arrangement of the human eye and the photographer's camera?

In the eye the focusing is accomplished by an increase or decrease in curvature of the crystalline, while the retina remains in a fixed position to receive the image. In the camera, the curvature and position of the lens is fixed and unchanging, while the screen is adjustable so that it can be moved to the position where it will receive the image most distinctly.

If diplopia can be produced with a three-degree prism base in, what is the trouble?

When a prism is placed before the eyes base in, the external recti muscle are brought into action to prevent diplopia; therefore, if diplopia is produced, it must be because of deficiency in power of these muscles.

What is diplopia and in what way does it differ from heterophoria?

Diplopia means double vision. It is only a symptom, but it is one that is self-evident and needs no test to discover it.

Heterophoria is a generic term used to indicate some imbalance of the extra ocular muscles. It is, however, a latent condition, and its existence is detected only by the employment of certain tests.

Is the refraction of the eye affected by spasm of the ciliary muscle and if so in what manner?

Spasm of the ciliary muscle by adding to the dioptric power of the eye changes its apparent refraction. In hypermetropia such a spasm conceals part or all of the error, so that not sufficient convex will be accepted or even concave lenses may be called for instead.

In emmetropia, spasm makes the eye apparently myopic; and in myopia causes too strong a concave lens to be chosen.

What must be the form of a cone of light entering the static myopic eye so as to be focused on the retina? What must be the form of cone of light entering the static hypermetropic eye so as to focus on the retina?

As the myopic eye is adapted for divergent rays, the apex of the cone must be at the far point of such eye. And as the hypermetropic eye is adapted only for convergent rays, the apex of the cone must be at the retina.

In the first case the cone of divergent rays is a natural condition as light proceeds from close objects; in the second case the cone of convergent rays must be produced artifically by a convex lens in front of the eye.

Supposing a person otherwise emmetropic had got a high degree of astigmatism, what will he probably complain of in the way he sees objects; in other words how will he, never having heard of astigmatism, describe his visual defects? How could you make an emmetrope see things as though he were astigmatic?

This question is worded strangely as it is not customary to refer to an eye as being emmetropic if it has a high degree of astigmatism.

If one meridian of an eye was emmetropic and the other chief meridian was highly ametropic, as for instance in simple myopic astigmatism, such an eye would see clearly in one meridian and indistinctly in the other.

For instance, he might be able to see clearly telegraph poles and at the same time the telegraph wires might be indistinguishable. Or he might be able to see the hands on the clock and tell the time of day at certain periods of the 24 hours and not at others; such cases having occurred and been reported before astigmatism was understood, as periodical obscuration of vision.

An emmetrope can be made artificially hypermetropic astigmatic by placing a concave cylinder in front of his eye, and myopic astigmatic by placing a convex cylinder in front of his eye.

If a person aged twenty is hypermetropic 4 D., how much accommodation would be used when reading at 40 cm. while wearing + 1.75 D. sphere? How much accommodative power has he to spare and what glasses ought he to use?

This person must first correct his hypermetropia by the use of 4 D. of accommodation, and then he must use another 2.50 D. of accommodation to see at 40 cm., which equals 6.50 D., but since he is wearing + 1.75 D. spheres, the effort of accommodation would then be

$$6.50 \text{ D.} - 1.75 \text{ D.} = 4.75 \text{ D.}$$

The average amplitude of accommodation for an emmetropic eye at twenty years is 10 D., but since this person must use 4 D. of it to overcome his hypermetropia, the amount of accommodation available would be reduced to 6 D. If he is wearing the + 1.75 D. spheres mentioned, this would be increased to 7.75 D.

As to what glasses he should wear, this is a question that cannot be answered offhand. Ordinarily, it is not wise to correct more than the manifest error in any particular case, and this is a variable quantity. We presume that the + 1.75 D. spheres he is wearing represent the manifest hypermetropia and unless there are some special symptoms we would not consider a change. If, however, there were urgent symptoms calling for relief, then we would increase the lenses even to the extent of slight fogging.

Describe the crystalline lens from an optical point of view omitting all reference to its minute anatomy. What would be the optical effect of removing the crystalline lens altogether?

The crystalline lens is a bi-convex lens, about 8 mm. wide and 3.6 mm. thick. The nucleus has a higher index of refraction than the cortex, and hence the crystalline may be regarded as a biconvex lens of high power enclosed between two convexo-concave lenses of lower power, and as a result of this construction, the refractive power of the lens is greater, the alteration in curvature in the act of accommodation is made possible and spherical aberration is reduced.

The radius of curvature of the anterior surface of the crystalline is about 10 mm. and of the posterior surface 6 mm.

The index of refration of the crystalline is about 1.44, but on account of the media on both sides of it having an index of 1.33, the relative index of refraction of the crystalline lens is expressed by

$$\frac{1.44}{1.33} = 1.08$$

Its refractive power is from 15 D. to 20 D.

The removal of the crystalline makes the eye hypermetropic to the extent of only 10 D., which is not as much as indicated by the power of the crystalline lens in the eye, where its effect is lessened by being in contact with media approximating its own index of refraction.

What do you understand by the terms "amplitude of accommodation" and "range of accommodation?" Illustrate these terms in the case of an emmetrope aged 20, a myope of 3 D. aged 20 and a hypermetrope of 3 D. of the same age. Where would the near point be situated in each case?

The amplitude of accommodation in all the cases mentioned at 20 years of age is 10 D., but the positive refracting power and the near point vary in each case.

In emmetropia the positive refracting power is identical with the amplitude of accommodation and the near point is 4 inches.

In a hypermetrope of 3 D. the positive refracting power is reduced to 7 D. and the near point recedes to 5½ inches.

In a myope of 3 D. the positive refracting power is increased to 13 D. and the near point approaches to 3 inches.

In the application of the laws of conjugate foci to the human eye, what two points are conjugate?

One conjugate focus is on the retina where the distinct image must be formed. The other conjugate focus will be the object which emits the rays that go to form the retinal image.

Or we may say that the far point and the retina are conjugate to each other.

The standard position of the retina is at the posterior principal focus of the refracting system of the eye, which is the focus for parallel rays proceeding from infinity.

In emmetropia the retina and infinity are at conjugate foci.

In myopia the retina lies beyond the principal focus; and in hypermetropia it lies in front of it.

When the retina is situated beyond the principal focus as in myopia, the emerging rays will be convergent and focus at its far point, which is then conjugate to the retina, these conjugate foci being on opposite sides of the refracting system and the image is negative.

Anatomy of Eye

Name the intrinsic and extrinsic muscles of the eye and the nerves supplying innervations to each.

The intrinsic muscles of the eye are:

(*a*) Ciliary muscle, supplied by the third cranial, or oculomotor nerve.

(*b*) The muscles of the iris, of which the sphincter is supplied by the third cranial nerve and the dilator by the sympathetic.

The extrinsic muscles are: External rectus, supplied by the sixth cranial nerve; internal rectus, superior rectus, inferior rectus, inferior oblique, supplied by third cranial nerve; superior oblique, supplied by fourth cranial nerve.

Name the bones of the orbit.

Frontal, sphenoid, ethmoid, superior maxillary, palate, malar and lachrymal bones.

Describe the iris and name its functions. Name the two muscles which control its movements. Name the nerve supply of each.

The iris is the terminal portion of the choroid, and is suspended in the aqueous humor in front of the crystalline lens. Its free border encircles the pupil and rests on the anterior surface of the capsule of the lens. The diameter of the iris is about 11 mm.

Its vascular stroma layer is composed of bundles of loose connective tissue and contains blood-vessels, nerves, lymph spaces, nucleated cells with pigment and the muscles of the iris.

The two muscles are the *sphincter*, which is a flat band 1 mm. in width, lying near the pupillary margin, and the *dilator*, whose fibres are arranged meridionally, extending from the ciliary margin of the iris to the pupil. Both muscles are involuntary. The former is supplied by the third nerve and the latter by the sympathetic nerve.

The iris is a diaphragm, changing the size of the pupil so as to regulate the quantity of light entering the eye, the movements being made unconsciously. These movements are induced reflexly, as by light, and directly, as by the accommodation.

Describe the crystalline lens and name and describe its functions.

This is a transparent lenticular body, classed as biconvex, (the posterior surface showing the greatest convexity), resting in a depression in the anterior surface of the vitreous humor and supported by the suspensory ligament, or zone of Zinn. Early in life the lens substance is soft and of the same consistence throughout, but gradually the central portion hardens and in advanced age forms the nucleus. This hardening results in loss of elasticity and is made manifest by impaired accommodation. The lens substance is enclosed within an elastic strong membrane, called its capsule. The lens measures about 10 mm. transversely and 4 mm. in thickness.

The substance of the lens is composed of layers of elongated cells, called the lens fibers, which are united by a cement substance.

The function of the crystalline lens is to increase and decrease in convexity and thus provide for focusing upon the retina the rays of light proceeding from objects situated at different distances within infinity. During the act of accommodation the lens becomes more convex, especially upon its anterior surface. This increase in convexity is brought about by the action of the ciliary muscle acting upon the suspensory ligament.

Describe the anterior chamber of the eye.

The cavity in the anterior portion of the eye occupied by the aqueous humor is divided by the iris, which stretches across it from side to side, into two portions, called the anterior and posterior chambers. The anterior chamber is, therefore, that portion of the aqueous cavity lying in front of the iris and is bounded anteriorly by the cornea.

Which is the longest diameter of the eyeball? Why?

The anterio-posterior diameter is the longest because of the projection of the cornea.

In high hypermetropia, it is conceivable that this diameter may be shorter.

Give the location of the lachrymal gland. Describe briefly the lachrymal duct.

The lachrymal gland is a compound racemose gland of the size and shape of an almond and is lodged in a depression at the upper and outer portion of the orbit. Its concave under surface rests upon the globe of the eye, with the conjunctiva, superior and external recti muscles intervening. It is held in contact with the orbital periosteum by a few fibrous bands. Connected with the gland there are a number of ducts, from eight to twelve, which open by minute orifices in a row on the upper and outer part of the conjunctival reflection.

What is probably meant by the latter part of the question is a description of the *nasal duct.* This is a membranous canal about 3/4 of an inch long, extending from the termination of the lachrymal sac through the osseous nasal duct to the inferior meatus of the nose, passing in a direction downward, backward, and outward, its diameter being narrowest at its middle. Externally it is composed of fibro-areolar tissue and internally of mucous membrane, continuous with that of the nose and lachrymal sac.

Name the humors and the refracting media of the eye.

The humors from before backward are the aqueous humor, crystalline lens, and vitreous humor, which together with the cornea, form the refracting media of the eye.

How many muscles are there in each orbit? Give their names.

Answered above, to which, however, may be added the levator palpebrae superioris, which arises from the lesser wing of the sphenoid bone and passes forward to be inserted into the upper border of the superior tarsal cartilage and the skin.

What are the principal blood-vessels of the eye?

The ophthalmic artery enters the orbit by the optic foramen and gives off the following branches:

Lachrymal, supraorbital, superior and inferior palpebral, nasal, long, short and anterior ciliary, arteria centralis retinæ and infraorbital.

Name the nerves of the eyeball.

Optic nerve, the special nerve of sight. The motor nerves are the third, fourth and sixth cranial. The ophthalmic division of the fifth cranial nerve supplies general sensation. The sympathetic. The long and short ciliary. Lachrymal, frontal and orbital.

What are the folds of the conjunctiva called?

The folds formed by the passage of the conjunctiva from the lids to the eyeballs are called the superior and inferior palpebral folds, the former being the deeper. The word fornix is also used.

What are the appendages of the eye?

The appendages of the eye are the eyebrows, or supercilia; the eyelids, or palpebræ, with their lashes; the mucous membrane, or conjunctiva, and the lachrymal apparatus, consisting of the lachrymal gland, with its ducts, the canaliculi, the lachrymal sac and the nasal duct.

Describe the posterior chamber of the eye.

This term may have two meanings. It is possible that the examiners may have had reference to the vitreous chamber, which lies behind the crystalline lens and in front of the retina and is filled with a jelly-like substance, which not only allows the light to pass freely but also gives form to the eye.

The term posterior chamber, or more properly, posterior aqueous chamber, is also given to that part of the aqueous chamber which lies behind the iris and in front of the crystalline lens. The posterior chamber is only a narrow chink between the peripheral portion of the iris, the suspensory ligament and the ciliary processes, and is filled with aqueous humor.

Describe the mechanism of the contraction and expansion of the pupil of the eye.

The pupil, being simply an aperture in the iris, its mechanism is supplied by the muscles of the latter, which consists of two sets of fibers.

The sphincter of the pupil, which is a narrow band of circular muscular fibers, surrounding the pupil on its posterior surface 5 mm. wide and supplied by the third nerve through the ophthalmic ganglion.

The dilator of the pupil, which consists of radiating muscular fibers converging from the circumference of the iris toward the pupillary margin, where they blend with the circular fibers and is supplied by sympathetic fibers from the ophthalmic ganglion.

The pupil contracts and dilates automatically on exposure to or protection from light, the greater part of these movements being due to the action of the sphincter muscle, which is the stronger of the two.

What is the canal of Schlemm and where is it located?

This canal, also called the circulus venosus ciliaris, is a small channel running completely around the eye at the sclero-corneal juncture. Its outer walls are dense, while the inner are composed of spongy, reticulated tissue, apparently continuous with the inner scleral process and closely united with the posterior limiting membrane of the cornea and with the pectinate ligament of the iris, and the meridonal fibers of the ciliary muscle.

The character of the canal of Schlemm, whether venous or lymphatic, was long a subject of controversy, but it is now regarded as a venous sinus, which, through the spaces of Fontana, stands in close relation to the anterior chamber on one hand and communicates directly with the anterior ciliary veins on the other. Usually the canal of Schlemm contains but little blood, because it is only a reserve reservoir for the storage of blood when temporarily retarded in its escape through the anterior ciliary veins. In order to maintain normal conditions of intraocular tension, the aqueous humor is constantly passing through the space of Fontana into the canal of Schlemm and thence into the communicating veins.

What kind of a membrane is the conjunctiva and where is it located?

The conjunctiva is a mucous membrane lining the lids and covering the anterior surface of the eyeball and, therefore, it is appropriately divided into the palpebral and ocular conjunctiva. The annular fold which marks the limit of the conjunctival sac is known as the fornix, which permits of free motion of the ball in all directions.

The ocular conjunctiva is smooth and glistening, while the tarsal conjunctiva shows a peculiar velvety appearance. The conjunctiva in many places is loosely attached and elastic, allowing it to be moved readily to and fro and at the same time affords an opportunity for the accumulation of extravasated fluids.

What is the function of the lachrymal gland and where is it located?

The lachrymal gland is located in a depression in the roof of the orbit at its upper and outer portion. Its function is to secrete a fluid called the tears, which keep the eye moist and lubricate it. Under the disturbing influence of emotion, a foreign body in the eye, and inflammation, an excessive secretion takes place, causing a running of the nose and an overflow on the cheeks.

How is the crystalline lens held in position?

The position of the crystalline lens is maintained by means of a series of delicate bands which pass from the vicinity of the ora serrata over the ciliary processes, to be attached to the periphery of the lens; these fibers constituting the suspensory ligament or zone of Zinn. This structure is of great importance, not only for the support of the lens, but also in effecting changes in the curvature of the lens in the act of accommodation. The suspensory ligament is a delicate annular band about 6 mm. in width, which blends with the periphery of the lens on one hand and with the hyaloid membrane in the vicinity of the *ora serrata* on the other.

The zone of Zinn is not a continuous membrane but a series of interlacing bands or fibers, which are divided into chief and

accessory. The chief zonular fibers constitute the principal union between the lens and the surrounding ciliary body, while the accessory fibers comprise numerous shorter bands, which act as bracers and binders to the chief fibers, and hence are important additions to the strength of the suspensory ligament.

What are the characteristics of the choroid?

This is the middle coat of the eyeball and is essentially a sheet of vascular connective tissue. It extends from the optic nerve entrance to the ora serrata, closely united to the retina, whose nutrition it furnishes. Although lining the sclerotic, its connection with the outer coat is not so firm.

The most conspicuous of the large blood channels are the four venous trunks the *venae vorticosae*, which pierce the choroid at its equator at equidistant points, toward which the smaller veins converge. The choroid is dark in color, fragile and easily torn.

What are the angles of the eyelids called?

They are called outer and inner *canthi*, from the Latin word meaning corners. The singular noun is *canthus*.

How is the eye protected from external injury?

The eyeball itself is protected from injury by being deeply placed in the orbit, the edges of which are dense and strong, particularly the upper one, which overhangs the eye and is capable of shielding it from a powerful blow, as is shown in the case of a "black eye," where the blackness is not in the eye but in the surrounding soft tissues, which are swollen and inflamed and filled with blood, while the eye itself peeps through them quite unharmed. If the force of the injury is from below the eye is not so well protected.

The contents of the eyeball are protected by the sclerotic, which is a dense, strong, fibrous coat; and, in addition, by reflex and automatic action, when any foreign body approaches the eye the muscles instinctively contract and the eye is immediately closed.

Name the humors of the eye and state in what respect they differ.

The humors of the eye from before backwards are the aqueous, crystalline and vitreous.

The aqueous humor has the consistency of water, with an index of refraction of 1.333.

The vitreous humor is thicker, of jelly-like nature, resembling the white of a fresh egg, with an index of refraction about the same as the aqueous.

The crystalline lens is of still greater consistency than the vitreous, with the nucleus denser than the cortex. The index of refraction of the crystalline as a whole is about 1.44.

They differ in their density and refractive power, the crystalline leading in each particular.

Describe the eyelids.

The lids from without inwards are composed of the following structures:

Skin, thin layer of connective tissue, fibers of the *orbicularis palpebrarum* which closes the lids, small plates of cartilage, known as the tarsal cartilages and composed of dense fibrous tissue, and giving form and support to the lids, Meibomian glands, whose oily secretion prevents adhesion of the lids and mucous membrane known as the conjunctiva.

In addition to the orbicularis muscle, there is the *levator palpebrae superioris*, which raises the upper lid and opens the eye.

The upper lid is much the largest and thus gives better protection to the eyeball. The opening between lids is the *palpebral fissure or commissure*, and the angles formed by the lids are the outer and inner canthi.

Name and briefly describe the coats of the eyeball.

The external coat is the sclerotic, a tough fibrous coat for protection.

The middle coat is the choroid, the vascular and pigmentary coat.

The internal coat is the retina, the nervous coat on which the images are formed.

Describe the cornea. Give its radius of curvature and its refractive index.

The cornea is the transparent anterior portion of the external coat. It is composed of five layers:

1. Epithelium.
2. Anterior limiting membrane, or Membrane of Bowman.
3. The proper substance of the cornea.
4. Posterior limiting membrane, or Membrane of Descemet.
5. Endothelium.

Its index of refraction is 1.33, and its radius of curvature 7.8 mm. to 8 mm.

Enumerate the various external motor muscles of the eyeball, and give the action of each. What is meant by conjugate movement of the eyes?

The superior, inferior, external and internal recti, the actions of which are to turn the eye up, down, out and in; and the superior and inferior oblique, which produce a wheel-like movement, the former rotating down and out, and the latter up and out.

The associated movements of the eyes are both eyes upward or downward, both eyes turn to right or to left, in all four of which the axes of the eyes remain parallel; and the two eyes turning inward in the act of convergence, where the parallel condition of the visual axes is destroyed.

Name the appendages of the eye.

The eyebrows, the eyelids, capsule of Tenon, conjunctiva, the extra-ocular muscles and the lachrymal apparatus.

What muscles are supplied by the third nerve, and what is the possible result if the impulses go wrong?

The third cranial nerve supplies the superior, inferior and internal recti, the inferior oblique, the ciliary muscle and the circular fibers of the iris. If there is any interference with its function, the action of one or more or all of these muscles will be impaired.

What are the abducens muscles of the eye, and why so called?

The external recti which turn the eye outwards; the word "abducens" is derived from two Latin words, meaning "to lead from."

What is the nature of the aqueous humor of the eye?

It is a watery fluid with a slight quantity of chloride of sodium in solution, and with an index of refraction about the same as water. If lost by injury or operation, it is quickly replaced. It has free communication with the spaces of Fontana, the canal of Schlemm and the lymphatics of the eye.

Describe the Meibomian glands?

These are the sebaceous glands of the eyelids, numbering from 30 to 40 in the upper lid, and 20 to 30 in the lower. Each gland has a duct, these ducts terminating as minute points arranged in a row along the margin of the lid near its inner border. The oily secretion of these glands hinders the overflow of tears and prevents adhesion of the lids.

As a rule which meridian of the eye has the greater curvature?

This question should read which meridian of the cornea, and the answer would be the vertical.

Where is the fovea centralis and why is it so important?

It is a funnel shaped depression near the center of the macula latea. It is the region of most acute vision, and because this acuity of vision is confined to such a small point, the eye must move when scanning a surface of any size.

Its diameter is from 0.2 to 0.4 mm., and the retina at its bottom is thinner than at any other place. On account of this thinness of the retina allowing the pigment to show through, the fovea appears as a dark brown spot.

Ophthalmoscopy

Describe the indirect method of ophthalmoscopy, give the character of the image seen and state where it is located.

In the indirect method of the ophthalmoscope, a strong convex lens is used in connection with the instrument. This lens may be + 13 D. or + 16 D. and is held at its focal distance in front of the eye. The ophthalmoscope is held at a distance of 12 to 15 inches from the eye, and the light is reflected through the convex lens into the eye. The rays returning from the retina of the eye under observation form a real, inverted, aerial image between the lens and the ophthalmoscope. If the patient is requested to turn his eye in accordance with the observer's wishes, every part of the fundus may be brought into view. This aerial image may be magnified and hence better seen by rotating a convex lens of 3 D. or 4 D. into the sight hole of the instrument.

The indirect method gives a larger field than the direct, but the details are less magnified, usually about 5 diameters as compared with sixteen diameters in the direct. The stronger the condensing lens, the larger the field, but the smaller the details; the weaker the condensing lens, the smaller the view of the fundus, but the larger the details.

Name the various methods of using the ophthalmoscope. How do the images differ? What are the advantages of each method?

There are two methods of using the ophthalmoscope—the direct and the indirect.

In the direct the image is erect and magnified. In the indirect, inverted and smaller than in the direct.

The advantages of the direct method are the greater magnification and the disk seen in the erect position.

The advantages of the indirect method are the larger field of view, can be seen through a smaller pupil and not necessary to get so close to objectionable patients.

In what manner is the ophthalmoscope or mirror used in cases of matured cataract, so as to determine the extent of retinal light sensibility in support of a favorable prognosis to operation?

Before the whole lens has become opaque examination with an oblique light will throw a shadow of the iris on the cataractous part on the side from which the light comes, which shadow is absent when the cataract has become mature.

If the retinal sensibility is unimpaired, the perception of light is never lost even in mature cataract; hence when light is reflected into the eye the patient should be able to quickly recognize the direction in which it is moved.

How are errors of refraction detected by the direct method of ophthalmoscopy?

The accommodation of both optometrist and patient must be relaxed and the former must wear his correcting lenses or make allowance for his error.

Hypermetropia is detected and measured by the strongest convex lens with which the fundus can be seen; myopia by the weakest concave lens that makes the fundus clear, and astigmatism by the difference in the lenses required for vertical and horizontal vessels.

How is the refraction of the eye measured by the indirect method of ophthalmoscopy?

As the object lens is withdrawn, if the disk remains unchanged in size, emmetropia is indicated; if it diminishes in size, hypermetropia; and if it increases in size, myopia. This is a method for detection of these errors, but cannot be used for accurate measurements.

How is the examination with the ophthalmoscope made by the direct method?

Looking directly into the eye, examining patient's right eye, observer uses his right eye and holds ophthalmoscope in his right hand. Commencing the examination at a distance of at least ten or twelve inches and then without losing the reflex approaching

as close as possible in a slow and easy manner, until the full details of the fundus are distinctly visible.

How is the examination with the ophthalmoscope by the indirect method?

The observer does not have to get so close to his patient, but holds the ophthalmoscope at a distance of twelve inches. A strong convex lens is required, which is held at its focal distance in front of the eye. The light is reflected through the convex lens into the patient's eye and the slight movements made that may be necessary to bring the disk and vessels into view. The observer is supposed to see a real inverted image formed in the air between the lens and the ophthalmoscope, this image being also laterally transposed. In order to get a better view of the image the operator may use a convex lens (about 4 D.) in the sight hole of the ophthalmoscope.

Explain how the ophthalmoscope may be used to detect and measure errors of refraction?

By means of the direct method with the accommodation of both patient and observer at rest, the strongest convex lens or the weakest concave lens rotated into the sight hole of the instrument, with which the details of the fundus can be clearly seen, will represent the amount of hypermetropia or myopia respectively.

In what way does the picture of the retina as seen by the direct method of ophthalmoscopy differ from that seen with the indirect method?

In the direct method the image is erect and more magnified, with a restricted field. In the indirect method the image is inverted, less magnified, but with a larger field of view.

Why is refracting with the ophthalmoscope apt to be incorrect, and when will it be the most reliable?

Because of action of the accommodation in patient or optometrist. In order to obtain accurate results in measuring the refrac-

tion with the ophthalmoscope the accommodation of both observer and observed must be at rest, which is almost an impossibility.

The result of such a test would be most reliable if the accommodation of both was under the influence of a cyclopegic, or if both were past the presbyopic age. But as a matter of fact the ophthalmoscope has been supplanted by the retinoscope for measuring the refraction.

Where are the images formed in the direct and indirect methods of the ophthalmoscope?

In the direct method the image is virtual, erect and enlarged, and appears to be some distance behind the eye.

In the indirect method the image is real, inverted and smaller; it is an aerial image formed between the convex lens and the ophthalmoscope.

Which gives the best view of the fundus of the eye, the direct method of ophthalmoscopy or the indirect method?

The direct method gives an erect magnified view of the fundus. The indirect affords an inverted less magnified view but with a much larger extent of the surface of the fundus visible. On account of the magnification the direct method is usually considered the best.

Describe the optic disk as seen by the ophthalmoscope when in a normal condition. What peculiarities are sometimes noted in the fundus of the normal eye?

The optic disk is the most conspicuous landmark of the fundus and is the head of the optic nerve. It is nearly circular or slightly oval, with a diameter of 1.5 mm., which is magnified fifteen times by the direct method of the ophthalmoscope. The disk projects slightly above the level of the fundus and presents a central depression. The color is whitish or pinkish, and presents a marked contrast with the red of the fundus. The edges of the disk should be clearly defined.

There are variations in the color of the fundus, shape of the disk, width of the scleral and choroidal rings, distinctness of the

margins, color and size of the blood vessels, pulsation of retinal veins, etc.

In direct ophthalmoscopy an optometrist whose correction is + 2 D. sphere combined with a — 1 cylinder axis 180° finds that with naked eye he can see the blood vessels in the disk in the horizontal meridian with a + 1 D. lens in the ophthalmoscope, but requires + 2 D. lens to see the blood vessels in the vertical meridian. Write a prescription for the eye being examined.

An analysis of this sphero-cylinder will show that the optometrist has compound hypermetropic astigmatism, his correction being + 1 D. vertically and + 2 D. horizontally. In the first place it must be remembered that he sees the horizontal blood vessels with the vertical meridian of his eye, and the vertical blood vessels with the horizontal meridian of his eye. Therefore, if he requires + 1 D. to see the horizontal vessels that means + 1 D. for his vertical meridian, and if he requires + 2 D. for the vertical vessels, that means + 2 D. for his horizontal meridian.

As these are exactly the powers required in each meridian to correct his own astigmatism the refraction of the patient is proven to be emmetropic and no glasses are required.

What is the principal optical point in the use of the ophthalmoscope by the direct method?

That the rays emerging from the observed eye may be exactly focused upon the retina of the observer, and these emergent rays must be of such character, either naturally or made so artificially, that this may be accomplished with the accommodation of both parties at rest.

If the observer is emmetropic and the patient emmetropic also, the emerging rays will be parallel, and will focus on retina of observer without accommodative effort. If the patient is hypermetropic the emerging rays will be divergent and a convex lens will be required to focus them in observer's eye, presuming the accommodation of both to be passive.

If the patient is myopic the emerging rays will be convergent and a concave lens will be required for the observer to get a good view of the fundus.

In measuring ametropia by the ophthalmoscope, what must be allowed for and what function must be passive?

Any error of refraction in the eye of the optometrist must be allowed for unless he wears his correcting lenses, and the accommodation of both patient and observer must be at rest.

What is the main purpose of the ophthalmoscope?

To determine the transparency of the refracting media, to examine the fundus and note the condition of the optic disk and macula; in short to ascertain the absence or presence of disease, and in the case of the latter its character and location.

In the direct method of the ophthalmoscope the examiner finds that with the naked eye he can see the blood vessels of the disk in the horizontal meridian with a + 1 D. lens in the instrument, but requires a + 2 D. lens to see the blood vessels in the vertical meridian. The error of refraction in the examiner's eye is corrected by + 2 D. S. ⊂ − 1 D. cyl. axis 180°; what is the correction for the eye under the examination?

In the estimation of the refraction of an astigmatic eye by the direct method of the ophthalmoscope, it must be remembered that when looking at a vertical blood vessel the observer sees it through the horizontal meridian, and when viewing a horizontal vessel, through the vertical meridian.

The wording of this question is ambiguous, as for instance, the statement "the blood vessels of the disk in the horizontal meridian." We do not know if the framer of the question means the vertical vessels which must be seen through the horizontal meridian or the horizontal vessels which would be seen through the vertical meridian.

Judging from the correcting lenses of the examiner, we know his vertical meridian is hypermetropic 1 D., and his horizontal meridian hypermetropic 2 D., and as he is making the examination with his naked eye, this error of refraction must be allowed for. If the "vessels in the horizontal meridian" means vertical vessels seen through the horizontal meridian, for which the correction is + 1 D., while the refraction of this meridian in

the examiner's eye is hypermetropic 2 D., we must assume the patient is myopic 1 D. in this meridian.

And from a like point of view, if + 2 D. is the correction in the sight hole of the instrument for the vertical meridian, while the examiner is hypermetropic only to the extent of 1 D. in this meridian, then the presumption is that the patient is also hypermetropic 1 D. in this meridian.

The patient's correction for the two meridians would be − 1 D. cyl. axis 90° $\subset\!\supset$ + 1 D. cyl. axis 180° or − 1 D. $\subset\!\supset$ + 2 D. cyl. axis 180°.

But if the words "vessels in horizontal meridian" mean horizontal vessels, then the + 1 D. required is the correction for the vertical meridian. And as this + 1 D. is required to correct the examiner's hypermetropia in this meridian, we must assume the patient's refraction is emmetropic in this meridian.

And in like view of the case the + 2 D. required for the vertical vessels, would indicate the correction for the horizontal meridian. And as a lens of like amount is required to correct the examiner's hypermetropia in this meridian, the inference is the patient is emmetropic in this meridian.

From the latter interpretation of the case, we would have no prescription to write, as the patient would be shown to be emmetropic.

What are the optical principles of ophthalmoscopy in emmetropia by the direct method?

In ophthalmoscopy when the interior of the eye is illuminated by the mirror the fundus becomes a luminous body and gives off rays of light. As these rays pass out of the pupil they are subject to refraction of the dioptric media of the eye, and can be used by an observing eye so as to have an image of this fundus formed upon its retina. It was the theory of Helmholtz, who gave us ophthalmoscopy, to bring the illuminated fundus of the observed eye and the retina of the observing eye in positions of conjugate foci.

He reasoned that if the fundus of an eye became the source of light, the rays in passing out through the optical system of the eye would be refracted and proceed toward the conjugate focus of the object from which they came. If now the eye of

an observer could be placed in the path of these emergent rays so that they could be focused on its retina, the fundus from which these rays proceeded could be seen in all its details.

In emmetropia the rays will emerge from the observed eye parallel. If now the eye of the observer that is placed in the path of these returning rays is also emmetropic and as such adapted for parallel rays, the retina of the observed eye and of the observer's eye will be at conjugate foci, and an image of the fundus of the first will be formed on the retina of the second. Therefore an emmetropic eye can see clearly the details of the fundus of another emmetropic eye when both eyes are in a static condition and without the intervention of any lens.

What are the optical principles of ophthalmoscopy in myopia by the direct method?

In myopia the rays as they emerge are convergent toward the far point situated at some finite distance. The eye of the observer if emmetropic and as such adapted for parallel rays, could not focus these convergent rays on its retina.

In order to accomplish this, the rays must first be made parallel, which can be done by the interposition of a concave lens of such strength as will lessen the convergence of the rays and make them parallel. The negative focus of this lens will coincide with the location of the far point and the amount of myopia of the observed eye.

In this way the opthalmoscope may be used in the direct method to measure the degree of myopia. When the emmetrope looks into the eye of a myope, the fundus is very much blurred. A concave lens rotated into the sight hole of the instrument clears it up and the weakest lens that affords the clearest view of the optic disk and vessels will be the measure of the myopia; such lens making the emergent convergent rays parallel and bringing the retinæ of the two eyes into positions of conjugate foci.

What are the optical principles of ophthalmoscopy in hypermetropia by the direct method?

In hypermetropia the far point is negative and the rays as they emerge from the observed eye are divergent. The eye of

the observer if emmetropic and in a static condition, when placed in the path of these divergent rays, is unable to focus them upon its retina until they have been rendered parallel.

This can be accomplished by the interposition of a convex lens, whose focus would correspond to the negative focus back of the retina. The two retinæ are then placed in the positions of conjugate foci and the image of the fundus of the observed eye is formed on the retina of the observing eye.

A convex lens is rotated in the sight hole of the instrument and the strongest convex lens with which the clearest view of the fundus can be obtained will be the measure of the hypermetropia, such lens making the emerging divergent rays parallel and bringing the retinæ of the two eyes into positions of conjugate foci.

What are the optical principles of ophthalmoscopy by the indirect method?

The convergent rays that emerge from a myopic eye form an inverted image of the fundus of such eye at the far point, and if the observer places himself at the proper distance so that his own far point coincides with this image he will be able to see it distinctly.

In the indirect method of the ophthalmoscope we make the observed eye artificially myopic by means of a strong convex lens placed in front of it. It is customary to use a + 20 D. lens, which in the case of an emmetropic eye would form an inverted image of the fundus 2 inches in front of the lens, which would then be its conjugate focus.

An emmetropic observer at the usual reading distance by the aid of his accommodation, would be able to bring his far point to the position of this image, which would then be pictured on his retina.

If the eye under examination be myopic the aerial image will be a little closer, and if the eye be hypermetropic a little farther, than in emmetropia.

Should the observer be presbyopic and unable to use his accommodation, a convex lens rotated into the sight hole of the ophthalmoscope whose focal length would coincide with the aerial image would render the rays coming from it parallel, so that they could be focused by the eye of the observer.

If the observer is hypermetropic a stronger lens will be necessary; if myopic a weaker lens or no lens at all if the myopia was of such amount that its far point coincided with the aerial image.

Retinoscopy

Where is the nodal point of the observing eye with respect to the observed fundus located when the point of reversal in skiametry has been reached?

Conjugate to it.

Describe the behavior of the plane and of the concave mirror in skiametry.

The rays of light proceeding from the round opening in the chimney are divergent, and after striking the plane mirror are reflected in a continuance of the divergence, just as if they came from a point as far back of the mirror as the chimney is in front of it; hence, the shadow moves with in hypermetropia and emmetropia, and against in myopia.

With the concave mirror, on the other hand, the rays which leave the source of light as divergent, are reflected from the mirror convergently and brought to a focus and cross before entering the observed eye, and consequently the shadow moves against in emmetropia and hypermetropia, and with in myopia.

In both cases we proceed to estimate the refraction in the same way, that is, by neutralization by the indicated lenses.

What is indicated by the form of the shadow in skiametry? by the direction of the shadow? by the speed of the shadow?

1. The form of the shadow indicates the character of the error, whether astigmatic or spherical. If the shadow is curved or crescent-shaped at its edge, the indications point to simple myopia or hypermetropia. If the edge is straight or shows a banded appearance, the indications point to astigmatism.

2. The recognition of the direction of the shadow is a most important point, as it indicates the character of the refraction.

Using the plane mirror, if the direction is "with," it may be emmetropia or myopia less than 1 D., but we usually suspect

hypermetropia, which is proven to be present if the movement continues "with" after a + 1 D. lens is used to neutralize the one meter distance. If the direction is "opposite," the indications are for myopia of more than 1 D.

3. The speed of the shadow is affected by the movement of the mirror itself but making due allowance, the speed indicates if the error is high or low. When the refractive error is high, there is a slowness in the rate of movement of the shadow calling for a strong lens for its neutralization; whereas, when the movement seems to be fast, the error is likely to be low and call for a weak lens.

Where is the observing eye with the concave mirror located when the shadow movement is with the mirror?

Beyond the point of reversal.

How is the shadow movement in skiametry affected by low degrees of ametropia? Give the reason.

In low forms of ametropia the movement is fast because of the nearness of the point of reversal. The nearer to the point of reversal the faster the movement, because at this point the emergent rays from the observed eye are conjugate to the observing eye.

Give and explain the reason for a straight-lined contour of the shadow in skiametry.

A straight edge of the shadow indicates astigmatism, and is due to the fact that the emergent rays from the observed eye are refracted by the two chief meridians of the eye, one of least and one of greatest curvature, and as a result the focus could never be round or a point, but always oval or a line.

What kind of lens should be placed before the observed eye to produce neutralization when the observer with the concave mirror finds a shadow movement against the mirror?

Convex.

With respect to the degree of ametropia what may be deduced from a bright retinal reflex in skiametry?

In high errors the reflex is dull; in low errors it is bright.

In what respect does the dynamic method of skiametry differ from the static method?

In static skiametry the test is made with the ciliary muscle at rest. For this purpose a cycloplegic is sometimes used by medical men, while optometrists endeavor to get the same result by darkening the room and asking the patient to look carelessly at some distant object.

Dynamic skiametry is the opposite of static, and signifies the use of some force, which in the case of the eye is known as the accommodation. The test is made while the accommodation is in action, which is done by asking the patient to read test letters placed on the examiner's brow or attached to his mirror.

In static skiametry with the plane mirror, the operator working at one meter, no movement of the shadow is found in the vertical meridian; with a 1 D. spheric lens placed before the eye there is no movement of the shadow in the horizontal meridian. State the nature and the amount of the ametropia. What was the direction of the shadow movement when the mirror was rotated horizontally before the imposition of the lens?

If with plane mirror at one meter no movement is found in vertical meridian, the refraction of this meridian is myopic 1 D. If with + 1 D. lens there is no movement in the horizontal meridian, this meridian is emmetropic. The case then is one of simple myopic astigmatism, and would be corrected by a − 1 D. cyl. axis 180°.

The direction of the shadow in the horizontal meridian before the use of the convex lens, would be "with."

In skiascopy what two points are conjugate foci?

The retina and the point of reversal.

With the plane mirror, what is the direction of the shadow movement when the observer is within the point of reversal?

With.

In dynamic skiametry, with fixation at 40 inches, the point of reversal in the vertical meridian is found at 26 inches, + 2.50 D. lens being before the observed eye and at 20 inches in the horizontal meridian with − 1.25 D. lens before the observed eye. What is the kind and amount of ametropia?

Mixed astigmatism. Vertical meridian hypermetropic 2 D. and horizontal meridian myopic 2.25 D.

Correcting lens: + 2 D. cyl. axis 180° ⊂ − 2.25 D. cyl. axis 90°.

Put the following back to the retinoscope findings after reversing the shadow from 40 inches: − .50 ⊂ − .25 × 50.

If we reduce this sphero-cylinder to a cross cylinder, we have

− .50 D. cyl. axis 1.50 ⊂ − .75 D. cyl. axis 60°

which would indicate a myopia of .50 D. in the 60th meridian and of .75 D. in the 150th meridian.

Inasmuch as when working at 40 inches we must add − 1 D. to the retinoscopic findings, therefore the latter must have been

+ .50 D. in the 60th meridian
+ .25 D. in the 150th meridian.

Dark room findings:

O. D. + 1.50 axis 90° ⊂ + 3 axis 180°
O. S. + 2.25 axis 90° ⊂ + 1.75 axis 180°

Write the prescription.

If we take this literally and make allowance for a working distance of 1 D., the prescription would be

O. D. + .50 D. sph. ⊂ + 1.50 D. cyl. axis 180°
O. S. + .75 D. sph. ⊂ + .50 D. cyl. axis 90°

But usually in retinoscopy we find the lens that corrects each meridian and then we have to deal with meridians instead of as above with axes.

Usually the dark room findings come to us in this shape:

O. D. + 1.50 vertically — + 3 horizontally,
O. S. + 2.25 vertically — + 1.75 horizontally,

which means that the lenses mentioned neutralize the movement in the meridians mentioned. Then making the allowance of 1 D. and remembering that axes are at right angles to meridians, the prescription would read:

O. D. + .50 D. sph. ⊃ + 1.50 D. cyl. axis 90°
O. S. + .75 D. sph. ⊃ + .50 D. cyl. axis 180°

What is meant by the statement in skiascopy that the shadow moves with the mirror, or the shadow moves against the mirror?

When the patient's pupil is properly illuminated the observer will see a bright reflex from the pupillary area. As the mirror is turned the illumination moves off followed by the shadow, thus causing the movement of the shadow.

The illumination on the patient's face always moves in the same direction as the mirror is rotated, but not necessarily so in the pupil, where it sometimes appears to move opposite, and hence we speak of the shadow moving "with" or "against" the movement of the mirror.

What characteristic conditions exist when the point of reversal is reached?

At the point of reversal no definite movement of the retinal illumination can be made out, and while the pupil is uniformly illuminated it shows a duller reflex than when within or beyond this point, and the shadow will be absent.

What difference is observed in the directions of the movement of the facial and retinal illuminations by the plane and the concave mirror respectively?

The movement on the face is always the same as the mirror, whether it be convex or concave.

In the pupil the movements caused by the plane and the concave mirror are the reverse of each other, and they also vary with the condition of refraction.

In emmetropia, hypermetropia and myopia less than 1 D. the movement is *with* when using a plane mirror and *against* when using a concave mirror.

In myopia greater than 1 D. the movement is *against* with a plane mirror and *with* when using a concave.

With respect to the point of reversal, where must the observer be located to see (a) the shadow movement directed the same as the plane mirror; (b) the shadow movement directed opposite to the plane mirror; (c) the shadow movement directed the same as the concave mirror; (d) the shadow movement directed opposite to the concave mirror?

a. Inside the point of reversal.
b. Outside the point of reversal.
c. Outside the point of reversal.
d. Inside the point of reversal.

What may be discovered by dynamic skiametry? In what respect does the dynamic method differ from the static method?

The object of dynamic method is to discover spasm of the accommodation. It differs from the static method in that a definite amount of accommodation is brought into action according to the distance of the point of fixation, whereas in the static method the effort is to keep the accommodation at rest.

Which focal point is sought to be determined by skiametry and what relation exists between it and the retina of the observed eye?

The anterior focal point which would be conjugate to the retina of the eye under observation.

Describe the respective shadow movement with the plane and concave mirror, and state the advantage, if any, of the former over the latter?

With the plane mirror the shadow movements are in the same direction as the movements on the face when the eye

of observer is inside the point of reversal, and in the opposite direction to the movements on the face when the observer's eye is beyond the point of reversal.

The movements caused by a concave mirror are just the reverse in each case to those caused by a plane mirror.

The advantages of the plane mirror are that it is simpler and easier and can be used at any distance, whereas with the concave mirror the eye under observation must be at such a distance that the rays of light from the mirror come to a focus and cross before entering it.

How does the observer decide that the point of reversal has been reached?

The point of reversal is reached when the movements have been neutralized, or when it is impossible to determine in which direction the shadow appears to move. This is not always an easy matter, and the ability to quickly find the point of reversal comes only after extended practice.

Perhaps the better way for a beginner is to make or estimate between the lens that just makes the movement with and one that just turns it against. For instance, if with + 2 D. the movement is still with and with + 2.50 the movement has turned against, we have narrowed the point of reversal down to a point between the strength of these two lenses.

Describe the appearance of the retinal illumination in pronounced astigmatism.

As a band of light which is characteristic of astigmatism. If the spherical error be high and the astigmatism slight, the band of light will not be noticeable on first inspection, not until the axial error has been at least partly corrected, and becomes brightest when fully corrected.

Describe the directions of the real movement of the facial and retinal illuminations by the plane and the concave mirror respectively.

The facial illumination is always in the same direction as the movement of the mirror, whether it be plane or concave.

With a plane mirror the retinal illumination is always in the same direction as the movement of the mirror, whether the case be one of emmetropia, hypermetropia or myopia. The concave mirror causes reverse movements.

Describe the directions of the apparent movement of the facial and retinal illuminations by the plane and the concave mirror respectively.

The apparent movement of the retinal illumination depends upon whether the observer is within or beyond the point of reversal, or the point conjugate to the retina of the observed eye.

Using a plane mirror if the observer is within the point of reversal (as in emmetropia and hypermetropia) the movements will be with. If observer is beyond the point of reversal (as in myōpia greater than 1 D.) the movements will be against.

Using a concave mirror, if the observer is within the conjugate point, the movements will be against; if beyond the conjugate point, with.

Explain the dynamic method of skiametry. State the purpose of this method.

In the dynamic method of skiametry a card of letters is attached to the retinoscope or placed on the brow of the examiner, at which the patient is asked to look, after which lenses are used in the customary way to find the point of reversal.

In this method a definite amount of accommodation is used, depending upon the distance of fixation, in this way reducing the tendency to spasm. The test can be made at any distance, and the result represents the amount of defect, no allowance to be made for the working distance.

If with the plane mirror before the static eye, ã shadow movement against the mirror is neutralized in the horizontal meridian by – 1 D. lens of 40 inches and in the vertical meridian by the same lens at 30 inches (a) what will be the movement at 20 inches? (b) what is the amount of ametropia?

As the mirror must be moved up to 30 inches in order to neutralize the vertical meridian, this meridian must be .33 D. more myopic. As the rule is to add − 1 D. to the retinoscopic findings, we have − 2 D. as the measure of the horizontal meridian, and − 2.33 D. as the measure of the vertical meridian. This is a case of compound myopic astigmatism, and the correcting lens would be

− 2 D. sph. ⊂ − .33 D. cyl. axis 180°

At 20 inches there would be no movement in the horizontal meridian because neutralized by the 2 D. of myopia in this meridian, while in the vertical meridian there would be a movement *against*.

With a + 1 D. lens before the static eye and the plane mirror at 1 meter the shadow movement is with the mirror in the horizontal and against it in the vertical meridian; it is also found that there are other superposed lenses of 1 D., each of which separately neutralizes these movements. Give the character of the ametropia and of the lens that corrects it.

If with + 1 D. lens before the static eye, to neutralize the distance, the movement is with in the horizontal meridian, hypermetropia is proven, and if this movement is neutralized by another 1 D. lens, it must be a + 1 D., which would be the measure of this meridian.

If in the vertical meridian the movement is against myopia is proven, and if this movement is neutralized by a 1 D. lens it must be a − 1 D. lens, which would be the measure of this meridian.

The case is therefore one of mixed astigmatism and the correcting cross-cylinder would be

+ 1 D. cyl. axis 90° ⊂ − 1 D. cyl. axis 180°

which can be transposed to

− 1 D. sph. ⊂ + 2 D. cyl. axis 90°

A patient, while wearing − 2 D. sph. lenses under the dynamic test, neutralizes the shadow movement during fixation up to 40 cm. Give his amplitude of accommodation and the distance of his near point without glasses.

In order to neutralize the movement at 40 cm. 2.50 D. of accommodation is necessary, and as a further 2 D. of accommodation must be used to overcome the − 2 D. lenses worn, the amplitude of accommodation must be 4.50 D., which would represent a near point of 9 inches.

A young hyperope, having normal acuteness of vision, either with or without + 0.5 D. lenses, being subjected to the dynamic test, is found to require + 1 D. lenses to arrest motion of the shadow for all proximate distances up to 25 cm. Which lenses should be given him for reading?

The + .50 D. lenses represent the amount of manifest hypermetropia as measured by the trial case, and + 1 D. the amount of total error as measured by the dynamic method of retinoscopy.

Theoretically it would be proper to give him the full correction of + 1 D. for reading, but practically it is sometimes advisable in young people to slightly undercorrect.

By static retinoscopy at 40 inches the vertical meridian of the eye is found to neutralize with a + 1.75, and the horizontal meridian with a + 1.50. What is the correction for distance?

After making allowance for the working distance of 40 inches the refraction of the vertical meridian is hypermetropic .75 D. and of the horizontal meridian .50 D. The correcting lens would be

+ .50 D. sph. ⊃ + .25 D. cyl. axis 180°

If a person has an error of − 1 on + 2 cyl. axis 45°, what movements of shadows will be observed with the plane retinoscope?

Assuming the test is made at a distance of 40 inches, then in the meridian of the axis of the cylinder there would be no motion on account of the 1 D. of myopia, while in the 135th meridian the motion would be with the mirror.

In using the retinoscope with plane mirror, what causes the shadow, and why in hyperopia does the shadow move with the mirror?

In retinoscopy light is reflected by means of a mirror into the patient's eye where it falls upon the retina, making an area of light, which constitutes the retinal illumination. The shadow is the non-illuminated portion of the retina immediately surrounding the illumination.

In hypermetropia the rays emerge divergently, consequently the focus of such an eye is beyond the observer, in fact it is even beyond infinity; therefore, according to the laws of optics under such conditions, the shadow must move with the mirror.

In static skiametry, if the patient has 1 D. of myopic astigmatism in vertical meridian, at what distance will the neutral point be located in the horizontal meridian with a + 1 D. lens placed before the eye?

The patient has 1 D. of myopic astigmatism in the vertical meridian while the horizontal meridian is emmetropic. A + 1 D. lens placed before the eye would locate the neutral point of the latter at one meter, which is just the position of the retina of the observer. This is just the same as in emmetropia where + 1 D. lens is necessary to neutralize the movements at one meter.

With a + 3 D. lens before the static eye, where will the neutral point in the horizontal and vertical meridians be located for the ametrope whose correction is + 1 D. sph. $\bigcirc$ *+ 1 D. cyl. axis 90°?*

In this case the correcting combination would show that there was + 1 D. of hypermetropia in the vertical meridian, and 2 D. of hypermetropia in the horizontal meridian. Placing a + 3 D. lens before such an eye would make the vertical meridian myopic to the extent of 2 D. which would cause the neutral point to be located at 20 inches. The + 3 D. lens would make the horizontal meridian myopic to the extent of 1 D. thus causing its neutral point to be located at 40 inches.

What is the fundamental principle of the test with the skiascope?

The principle of retinoscopy is to find the point of reversal or the far point which either occurs naturally as in myopia or is artificially produced by convex lenses.

Which focal point is sought in the examination with the retinoscope, and what is the relation of that point with the retina of the eye?

The point of reversal where no motion is evident. This is the far point of the eye, naturally so in myopia and artificially produced by convex lenses in hypermetropia, and is conjugate to the retina.

In static skiametry with the plane mirror the operator, working at one meter, no movement of the shadow is found in the vertical meridian; with a + 1 D. sphere placed before the eye there is no movement of the shadow in the horizontal meridian. State the nature and the amount of the ametropia. What was the direction of the shadow movement when the mirror was rotated horizontally before the imposition of the lens?

Under the conditions named no movement of the shadow would show a myopia of 1 D. in the vertical, and a neutralization of the movement by a + 1 D. emmetropia of the horizontal meridian. This would indicate a myopia of 1 D. with the rule and would be corrected by − 1 D. cyl. axis 180°.

The direction of the shadow movement in the horizontal meridian before the imposition of the + 1 D. lens must have been with the light.

In static skiametry if the patient has 1 D. of myopic astigmatism, correcting lens axis vertical, at what distance will the point of reversal be located in the horizontal meridian with + 1 D. placed before the eye?

If the axis of the correcting cylinder is vertical the defective meridian is horizontal, being myopic to the extent of 1 D. A + 1 D. placed before the eye will make this horizontal meridian myopic that much more, and the point of reversal will then be located at 20 inches.

Since the layers that make up the retina of the eye are transparent how is it possible that we can see a reflex in retinoscopy?

Inasmuch as the retina has a pigment layer and besides is in close contact with the dark-colored choroid the light that is thrown into the eye is reflected from the retina and shows in the pupil as a bright-colored reflex.

Why do we seek in skiascopy to get neutrality of motion of the light reflex?

In order to find the point of reversal, which is the principle of retinoscopy, and by which the refraction of the eye is determined.

Why is it in skiascopy that it is not always possible to find neutrality of motion of the light reflex?

On account of irregularity of curvature of the crystalline lens or cornea.

What is meant in skiascopy by the term "with the mirror?"

That the movement of the retinal reflex in the pupil is in the same direction as the movement of the light on the face.

What is the appearance of the light in the pupil when there is astigmatism?

As a band of light.

Working with the plane mirror the vertical meridian is neutral at one meter and the horizontal meridian at half meter. What will be the movements in the two meridians at half meter?

The vertical meridian is shown to be myopic 1 D. and the horizontal meridian myopic 2 D. At half meter the movements in the vertical meridian would be with, while the horizontal meridian will be neutral.

In a certain eye the motion of one principal meridian is slightly against, while that of the other is slightly with. What will be the

effect of putting in front of the eye a high-power plus lens? Also the effect of using a high-power minus lens?

This would be a mild case of mixed astigmatism. A strong convex lens would make both meridians myopic, and the motion would be against in both. A strong concave lens would make both meridians hypermetropic, and the motion would be with in both, presuming a plane mirror is used.

A patient who is 1 D. hypermetropic and whose near point is at 13 inches requires a + 2 D. lens to show neutral motion by the dynamic method at 20 inches. What conclusions would you draw?

That there was a hypermetropia of at least 2 D.

What is the difference between a static test and a dynamic test?

In a static test the ciliary muscle is supposed to be passive or at rest, as in the objective tests. In a dynamic test the ciliary muscle is an action, as in the subjective tests.

A child shows by the static test with the skiascope an error of + 50 D. and by the dynamic test made at 16 inches he shows an error of + 1.25 D. What glasses would you recommend, and why?

The dynamic test shows that with a relaxation of accommodation the error is equal at least to 1.25 D. We hardly think it advisable, however, to prescribe so full a correction on account of the strong accommodation of youth. We would be inclined to make a compromise and order about + .75 D., if it seemed necessary to order glasses at all.

A patient sixty years of age shows by the static method with the skiascope 2 D. of hypermetropia and by the dynamic method at 20 inches a + 4 D. is required to neutralize motion. What is the prescription for distance and for reading at 16 inches?

+ 2 D. for distance, + 4.50 D. for reading.

Why are the movements of the edge of the light reflex in skiascopy in reversed directions, according as the plane or concave mirror is used?

Because in the case of the concave mirror the rays of light have been brought to a focus and diverged.

What is the difference in the real movement of the retinal illumination in skiascopy and the apparent movement?

The real movement corresponds to the movement of the retinoscope, while the apparent movement is dependent on the location of the focus, whether in front of or behind the instrument.

At what point is the astigmatic band the most noticeable?

The band of light is seen when one meridian is corrected and the meridian at right angles remains uncorrected or only partly corrected.

When the astigmatism is relatively high and the spherical error of small amount the band of light is usually evident on first inspection before any neutralizing lens is placed in position.

When does the edge of light reflex move the most rapidly, in high or in low errors?

When the refractive error is slight and a weak lens is required for its correction the movement is fast.

Upon what principle or principles is retinoscopy based? What is the scissors movement?

The principle of retinoscopy is the finding of the point of reversal, or the far point of a myopic eye, either naturally myopic or made so artifically by means of convex lenses that will bring the emergent rays of light to a focus at some definite distance.

In the so-called scissors movement there are two areas of light, or two shadows seen in the same meridian, occurring usually in astigmatism, and especially in irregular astigmatism. The

cause of the scissors movement is mostly attributed to a slight tilting of the crystalline lens.

In using the retinoscope what glasses would you wear in order to get the best results, and why is it necessary to wear glasses at all?

The reason why it is necessary for the observer to wear glasses, and the only reason, is that he may get the clearest view of the patient's pupil. For this purpose, if the observer have sufficient amplitude of accommodation, his distance glasses will answer until an age is reached when there is but little accommodation left, and then a convex lens must be added that will afford sharp vision at 40 inches.

In skiametry why is the point of reversal conjugate to the retina of the observed eye?

Because it is the neutral point, and the rays diverging from which would exactly focus on the retina of the eye.

Why is the plane mirror generally given preference over the concave mirror?

With the plane mirror the test can be made at any distance, whereas with the concave mirror care must be taken to see that the distance be greater than the focus of the mirror.

What is the difference of movement of the light edge with plane mirror as compared with the concave mirror?

Just the reverse. In emmetropia and hypermetropia where the plane mirror shows a *with* movement the concave mirror will show an *against* movement. In myopia where the plane mirror shows an *against* movement the concave mirror will show a *with* movement.

When is the retinal reflex the brightest with the plane mirror, and when with the concave mirror?

With both mirrors close to the point of reversal.

When does the light spot on the retina move the fastest, when the reflex is near or far from the neutral point?

Near the neutral point.

What are the characteristics of the light reflex at the reversal point in the human eye?

No definite movement of the retinal illumination can be made out, and the pupillary area is seen to be uniformly illuminated.

On what does the real movement of the retinal reflex depend?

On the direction in which the light is made to go by the tilting of the mirror.

On what does the apparent movement of the retinal reflex depend?

On the character of the emergent rays.

When the observer is nearer than the neutral point, what will be the direction of the shadow movement with the plane mirror?

With.

When the observer is farther away then the neutral point, what will be the direction of the movement with the concave mirror?

With.

In retinoscopy by the usual static method, if the patient has 2 D. of hypermetropic astigmatism, axis vertical, at what distance will the point of reversal be located in the horizontal meridian with a + 3 D. sphere placed before the eye?

If the axis of the correcting cylinder is vertical, the 2 D. of hypermetropic astigmatism would exist in the horizontal meridian. A + 3 D. sphere placed before the eye would over-correct this meridian and make it myopic to the extent of 1 D., in which case the point of reversal would be located at one meter or 40 inches.

In retinoscopy by the usual static method, with a + 2 D. lens before the eye, where will the point of reversal in the vertical and horizontal meridians be located for the ametrope whose correction is − 2 D. sph. − 1 D. cyl. axis 180°?

This is a case of compound myopic astigmatism in which naturally the point of reversal for the vertical meridian would be located at 13 inches and for the horizontal meridian at 20 inches. The addition of a + 2 D. before the eye would increase the myopia to that extent, and then the point of reversal for the vertical meridian would be moved up 8 inches and for the horizontal meridian to 10 inches.

Using the method of dynamic skiametry and working at 40 inches, a + 1 D. sphere causes reversal in the vertical meridian, while it requires a + 1.50 D. to cause reversal in the horizontal meridian, what is the kind and amount of ametropia?

In accordance with the theory of dynamic skiametry in which no allowance is to be made for the distance at which the test is made, this case would be one of compound hypermetropic astigmatism, showing 1 D. of defect in the vertical meridian and 1.50 D. of defect in the horizontal meridian, and the correcting lens would be + 1 D. sph. = + .50 D. cyl. axis 90°.

An eye tested with the retinoscope by the customary static method shows the following: Vertical meridian point of reversal at 18 inches and horizontal meridian point of reversal of 32 inches. What is the refractive condition of each meridian, what two sphero-cylinders may be prescribed for distance, and which one would you consider best?

Vertical meridian myopic 2.25 D., and horizontal meridian myopic 1.25 D.

The correcting sphero-cylinders are:

− 1.25 D. sph. = − 1 D. cyl. axis 190°

− 2.25 D. sph. = + 1 D. cyl. axis 90°

The latter would be considered best, because more periscopic and with a vertical axis.

With a + 1.50 in the trial frame, the 45th meridian of an eye shows the point of reversal at 27 inches, at the same time the motion in the 135th meridian is with. By changing the + 1.50 to + 2.75 the point of reversal in this latter meridian is found to be at 40 inches. What is the refractive condition of each meridian, and what two sphero-cylinders may be prescribed?

When the test is made at 27 inches, we must add − 1.50 D. to the lens that produces reversal, which in this case is equivalent to plano, showing the 45th meridian to be emmetropic.

When the test is made at 40 inches, we must add − 1 D. to the lens that produces reversal, which in this case would show a hypermetropia of 1.75 D. in the 135th meridian.

The correcting lens would be a plano-cylinder:

+ 1.75 D. cyl. axis 45°,

which, however, may be transposed into a sphero-cylinder:

+ 1.75 D. sph. = − 1.75 D. cyl. axis 135°.

With the retinoscope at a distance of 40 inches from the eye as in the usual static method, a + 5.50 D. lens is required to neutralize the 120th meridian, and a − .50 D. to neutralize the 30th meridian. What is the amount of astigmatism present in the eye?

This is ascertained by finding the difference between the two cylinders, or subtracting one from the other, which in this case, where one is plus and the other minus, would show 6 D. of astigmatism.

Suppose the 15th meridian of an eye is emmetropic and the 105th meridian is 2.50 D. hypermetropic; where is the point of reversal of each meridian when a − .50 D. lens is placed before the eye?

In the emmetropic meridian the point of reversal is at infinity, and in the hypermetropic meridian beyond infinity. A − .50 lens would make the point of reversal in the emmetropic meridian beyond infinity, and in the hypermetropic meridian still further beyond.

With a + 2.50 D. lens in the trial frame the point of reversal of the 30th meridian of an eye under test by the usual static method

of the retinoscope is found to be 32 inches. Changing the lens in the frame to a + 1.25 the point of reversal in the 120th meridian is found at 32 inches. What kind of astigmatism is present and what is its amount?

We must make allowance for the distance at which the test is made, adding a minus lens which corresponds to this distance. The lens which represents the working distance of 32 inches is 1.25 D.; therefore, we must add − 1.25 to the finding in each meridian. Adding − 1.25 to + 2.50 would show the 30th meridian to be hypermetropic to the extent of 1.25 D. Adding − 1.25 to + 1.25 would show neutralization and indicate the 120th meridian to be normal.

Therefore it is a case of simple hypermetropic astigmatism, and the correcting lens is + 1.25 D. cyl. axis 120°.

With a + 6 lens before the patient's eye the point of reversal for the 150th meridian is at 32 inches; for the 60th meridian at 16 inches. What would be the correction for distance?

To make allowance for the working distance of 32 inches, we must add − 1.25 D. to the neutralizing lens + 6 D., which shows a hypermetropia of 4.75 D. in the 150th meridian. For the distance of 16 inches we add − 2.50 D. to the same neutralizing lens, which shows a hypermetropia of 3.50 in the 60th meridian. This would call for

+ 4.75 D. cyl. axis 60° ⊂ + 3.50 D. cyl. axis 150°,

or,

+ 3.50 D. sph. ⊂ + 1.25 D. cyl. axis 60°.

Working at a distance of 40 inches the retinoscopic finding for the 180th meridian of an eye is + 5 and for the 90th meridian it is + 6. What would be the equivalent sphero-cylinders for distance correction?

To make allowance for the working distance of 40 inches we must add − 1 D. to both meridians, which would show the 180th meridian to be hypermetropic 4 D. and the 90th meridian hypermetropic 5 D., which would call for

$+ 4$ D. cyl. axis $90° \bigcirc + 5$ D. cyl. axis $180°$,

or,

$+ 4$ D. sph. $\bigcirc + 1$ D. cyl. axis $180°$.

Working at a distance of 27 inches from the eye in the static method of retinoscopy, the 15th meridian needs a + 2.50 D. to get a choked disk, while the 105th meridian needs + 3.50 D. The full correction for distance is prescribed and torics are ordered. On testing the torics with a lens measure one surface is found to be a − 7.50 D. sphere; on the other surface the 15th meridian shows + 8.50 and the 105th meridian shows + .50. Has the prescription been correctly filled?

In working at 27 inches we must add − 1.50 D. to the lens that produces neutralization, which would show a hypermetropia of 1 D. in the 15th meridian and of 2 D. in the 105th meridian. In estimating the power of the toric lens we find that the concave surface against the convex curves, leaves just the proper amount of convexity in each meridian to correct its hypermetropia. Hence the prescription has been correctly filled.

To what retinoscopic findings at one meter would a $+ 2 \bigcirc - 1.25$ *cylinder axis 90° correspond?*

This prescription when analyzed shows a hypermetropia of 2 D. in the vertical meridian and of + .75 D. in the horizontal. Inasmuch as working at one meter a − 1 D. must have been added to obtain this prescription, so now we must add + 1 D. to find the neutralizing lenses, which would show the retinoscopic findings to be + 3 D. vertically and + 1.75 D. horizontally.

With a + 6 D. sphere before the patient's eye, the 135th meridian shows the point of reversal at 40 inches, and the 45th meridian shows the same at a distance of 8 inches. What would be the distance correction?

As the point of reversal in the 135th meridian is at 40 inches, we add − 1 D. to the + 6 D., showing a hypermetropia of 5 D. in this meridian. The point of reversal in the 45th meridian

being at 8 inches, we add − 5 D. to the + 6 D., showing a hypermetropia of 1 D. in this meridian.

The correction for distance would be + 1 D. sph. ⊃ + 4 D. cyl. axis 45°.

If the findings for distance by the retinoscope are + 1.25 for the 60th meridian and + 1.75 for the 150th meridian, what two sphero-cylinders may be prescribed?

Assuming the examination was made at one meter, and adding − 1 D. for this distance, we find a hypermetropia of .25 D. in the 60th meridian and a hypermetropia of .75 D. in the 150th meridian. The correcting lens would be + .25 D. sph. .50 D. cyl. axis 60°, which could be transposed to + .75 D. sph. ⊃ − .50 D. cyl. axis 150°.

Change the retinoscopic findings + 2.50 D. in the 15th meridian at 40 inches, and + 3.50 D. in the 105th meridian at 32 inches to the proper sphero cylinder for distant vision?

For the 15th meridian after making an allowance of 1 D. for the 40 inches, the refraction would be 1.50 D. hypermetropia; and for the 105th meridian after making an allowance of 1.25 D. for the 32 inches, the refraction would be 2.25 D. hypermetropia. The lens thus indicated would be + 1.50 D. cyl. axis 105° ⊃ + 2.25 D. cyl. axis 15°, or + 1.50 D. S. ⊃ + .75 D. cyl. axis 15°.

A toric lens used for distance measures on its convex surface + 8 D. and on the concave surface it shows in the 30th meridian − 4.75 D. and in the 120th meridian − 4.25 D. To what retinoscopic findings at 40 inches does this correspond?

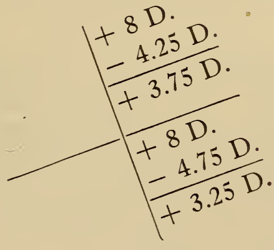


Fig. 34

A glance at the diagram shows that this toric lens has a power of + 3.25 D. in the 30th meridian and of + 3.75 D. in the 120th meridian. Assuming that the retinoscope had been used at the customary distance of one meter for which an allowance of 1 D. had been made, we must now add this same 1 D., which would make the retinoscopic findings + 4.25 D. in the 30th meridian and + 4.75 D. in the 120th meridian.

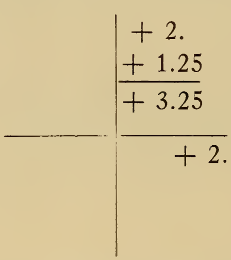
With + 2 D. the point of reversal for the 90th meridian is at 40 inches, and for the 180th meridian 32 inches; what would be the full correction for distance?

For the 90th meridian after making allowance of 1 D. for the 40 inches distance, the correction is + 1 D., and for the 180th meridian after making allowance of 1.25 D. for the 32 inches distance, the correction is + .75 D.

This would call for + .75 D. cyl. axis 90° ⊃ + 1 D. cyl. axis 180° which is transposed to this sphere cylinder:

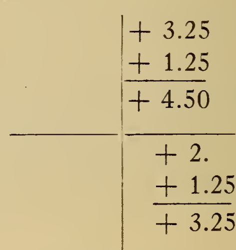
+ .75 D. S. ⊃ + .25 D. cyl. axis 180°.

A certain prescription is + 2 D. ⊃ + 1.25 cyl. axis 180°. Working with the retinoscope at 32 inches, where will the point of reversal be for both meridians?



Sphero cyl. powers

FIG. 35



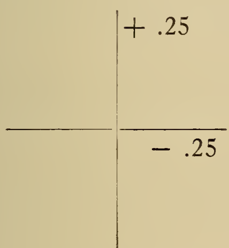
Retinoscopic findings

FIG. 36

The first diagram shows that the sphero cylinder has a power of + 2 D. horizontally and of + 3.25 D. vertically. And inasmuch as we must add 1.25 D. for the 32 inch working distance, the neutralizing lens would be + 3.25 D. for horizontal meridian and + 4.50 D. for vertical meridian.

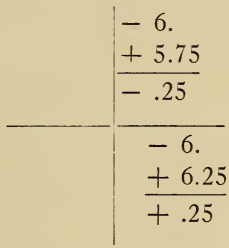
The reversal point of a certain eye is for the 90th meridian at 40 inches when a + 1.25 D. lens is used; for the 180th meridian testing at the same distance a + .75 D. is required. If a toric lens is prescribed, and on test with the lens measure one surface is found to be − 6 D. sphere, and the opposite surface to show + 6.25 D. in the 180th meridian and + 5.75 D. in the 90th meridian, has the prescription been properly filled?

After making the usual addition of − 1 D., we find the refraction of the vertical meridian to be + .25 D., and of the horizontal meridian to be −.25 D., as shown in first diagram:



Retinoscopic result

FIG. 37



Toric lens powers

FIG. 38

An analysis of the toric lens shows − .25 D. power vertically and + .25 D. power horizontally as per the second diagram.

A comparison of the two diagrams makes evident that the prescription has not been properly filled, but that the meridians have been reversed.

With a + 1 D. lens before a certain eye the point of reversal for the 90th meridian is at 53 inches, and the point of reversal for the 180th meridian is at 32 inches. What sphero cylinder will give full correction for distance?

Adding − .75 D. for the working distance of 53 inches, the correcting lens for the 90th meridian is + .25 D. And adding − 1.25 D. for the working distance of 32 inches, the correcting lens for the 180th meridian is − .25 D. This would call for + .25 D. cyl. axis 180° ⊂⊃ − .25 D. cyl. axis 90°, which is transposable to the following sphero cylinder: + .25 D. sphere ⊂⊃ − .50 D. cyl. axis 90°.

Can retinoscopy be practiced with the ophthalmoscope?

Yes, it can, but the ophthalmoscopic mirror is concave, while a plane mirror is preferred.

If a prescription calls for + 1 D. cyl. axis 90°, surface next to the eye to be deep concave, what kind of a lens would have to be made?

A toric lens, which is built up from a base curve of 6 D. on the toric surface. The outside surface of such lens would show a + 6 D. curve in the 90th meridian and a + 7 D. curve in the 180th meridian, while the deep concave surface towards the eye would be — 6 D.

Is it true as claimed that retinoscopy is best done with a plane mirror, and what is the reason?

Retinoscopy can be done with either the plane or concave mirror, but the plane is preferred, because in its use the distance at which the test is made need not be considered, where with the concave mirror care must be taken to keep beyond the focal distance of the mirror.

With a plane mirror at 20 inches in the usual static method of retinoscopy, a + 1 D. sphere neutralizes motion in all meridians; what is the full correction for distance?

In working at the customary distance of one meter, an allowance of 1 D. is made: so in working at 20 inches an allowance of 2 D. must be made.

We, therefore, add − 2 D. to + 1 D. and the results is − 1 D., which would be the full correction for distance.

In a certain person the error of refraction is corrected by the following formula: + 0.50 D. S. = + 1 D. cyl axis 45°. In the use of the retinoscope with the usual static method, what will be the movements of the fundus reflex at a distance of one meter without lenses?

This formula would indicate that the condition of the refraction was hypermetropic, one meridian to a greater extent than the other, and that therefore the emerging rays would be diver-

gent and would not meet in a focus; as a result of which there would be no neutral point between the eye under examination and the observer. Hence, the movement of the reflex in the pupil with the plane retinoscope at a distance of forty inches and without any lenses before the patient's eye, would be *with*. If a concave mirror was used the movement would be *against*.

What are the optical principles of retinoscopy with a plane mirror?

In retinoscopy the observer directs his attention to the movements of the shadowy edge of an aerial image of a bright spot formed from the light thrown by a mirror on the fundus of the observed eye, as it appears to pass across its pupil.

The direction of the movement in the pupil of the observed eye as it appears to the observing eye, will depend upon the position of the latter relative to the image formed at the conjugate focus of the fundus of the observed eye. Or in other words whether the observer receives rays which come from an aerial image of the bright spot, or the rays which proceed from the bright spot itself, before they have been united to form an image.

In this latter condition where the conjugate focus would fall behind the nodal point of the observing eye, the movements are always in the same direction as the mirror rotation, just as the retina of the eye would perceive the motion of any object in front of it.

But when the emerging rays from the observed eye are brought to a focus in front of the observing eye, the movement in the pupil will always be in a direction opposite to that of the mirror rotation.

If the observer places his eye in such a position that the conjugate focus of the observed eye falls upon it, no movement will be apparent.

In determining the refraction of an eye by retinoscopy, we find that the far point of the eye or the conjugate focus of its fundus, which we can do by artificially bringing the far point to any derived finite distance by means of a lens placed in front of the eye.

In myopia of 1 D. the fixed far point is at one meter, which is the position of the observing eye. The far point of any eye can

be brought to the same point of reversal by the proper lens placed in front of it.

The difference between the actual far point and 1 D. of myopia, is represented by the lens that was found necessary to bring the rays to a far point at one meter. Therefore, the far point is expressed by the difference between the number of the lens employed and 1 D.

In other word we add − 1 D. to the neutralizing lens. For example if + 1 D. was found necessary for neutralization, then + 1 D. − 1 D. = 0 or emmetropia.

If neutralizing lens was + .50 D. then + .50 D. − 1 D. = .50 D. or half diopter of myopia.

If the neutralizing lens was − 2 D. then − 2 D. − 1 D. = − 3 D. or three diopters of myopia.

The accommodation of the observed eye should be passive, as otherwise it is impossible to measure its static refraction.

But accommodation on the part of the observing eye need not be taken account of, as its use or non-use cannot change the result.

A patient has 2 D. of myopic astigmatism. If a + 2 D. sphere be placed before the eye, where will the point of reversal be for the horizontal meridian if the cylinder required to correct the error must be placed axis vertical?

If the error of refraction is simple myopic astigmatism, which is corrected by a − 2 D. cyl. axis 90°, we know the vertical meridian of the patient's eye is emmetropic, and the horizontal meridian myopic to the extent of 2 D.

When a + 2 D. sphere is placed before such an eye, the emmetropic vertical meridian will be made artifically myopic to the extent of 2 D. and the point of reversal will be 20 inches.

At the same time the natural myopia of the horizontal meridian will be artificially increased to 4 D. in which case the point of reversal will be at 10 inches.

Using the retinoscope at 40 inches with a + 1 D. sphere before the eye being examined, the horizontal meridian shows neutrality. When the + 1 D. sphere is removed, the vertical meridian shows neutrality. What is the error of refraction?

In working with the retinoscope at 40 inches, if a + 1 D. lens neutralizes the movement, emmetropia is indicated; therefore, in this case we must assume that the horizontal meridian is emmetropic.

When neutrality of movement occurs naturally without the intervention of any lens, myopia is indicated, the amount of which would correspond to the distance of the neutral point. In working at 40 inches, neutrality of movement would indicate myopia of 1 D., and therefore, in this case the vertical meridian is myopic 1 D.

If, then, the horizontal meridian is emmetropic, and the vertical meridian myopic 1 D., the error of refraction is simple myopic astigmatism, and the correcting lens would be − 1 D. cyl. axis 180°, which corresponds to astigmatism with the rule.

Physiology of Vision

What prevents an excessive amount of light from entering the eye?

It is the function of the iris to regulate the amount of light entering the eye, owing to the fact that exposure to light causes the circular fibers of the iris to contract and as the light increases in intensity the pupil assumes its smallest possible size, this contraction being the greatest when the light falls upon the macula.

At what age is the pupil of the eye the largest?

The size of the pupil is influenced by age, the color of the iris and the character of the refraction. Other things being equal the pupil is apt to be larger in youth, in dark eyes and in myopic eyes. The average diameter of the pupil is about 4 mm. and while we expect them to be of the same size in the same individual, yet slight differences in the width of pupils are not incompatible with health.

State the character of the retina. Give the relation of the retina to the optic nerve.

The retina is a continuation or expansion of the optic nerve. It is the nervous and percipient coat of the eye, and is intended to receive the images of external objects and transmit them to the brain. It is most sensitive in the region of the macula, and least sensitive near the *ora serrata.* It is transparent and hence invisible in health.

Describe a normal fundus.

The fundus is reddish in color, due to the choroid coat.

The optic disk is the most prominent feature of the fundus. It is about 1.5 mm. in diameter and is situated inwards from the posterior pole of the eye. It may be round, but is usually slightly oval vertically.

The central artery of the retina and its vein pass through the axis of the optic nerve. Near the center of the disk is usually seen a depression known as the physiologic cup.

The scleral and choroidal rings may be seen around the disk of light and dark color respectively.

The color of the disk is pinkish and distinctly lighter than the surrounding fundus. The veins are recognized by being larger in size and darker in color than the arteries.

The macula lutea is situated on the temporal side of the disk. It is oval in shape with its long diameter horizontal and it is darker in color than the rest of the fundus. At its center is the fovea centralis, which gives a reflex and appears as a bright spot.

Differentiate between the range and the power of accommodation.

The range of accommodation is the distance between the near point and the far point while the power of accommodation is the force which the ciliary muscle is able to exert to adapt vision for the near point.

What is accommodation and how is it produced?

Accommodation is the change in the dioptric condition of the eye whereby it is adapted for the perception of objects close at hand. The formation of a perfect image upon the retina depends upon the dioptric apparatus of the eye being so adjusted that the rays, diverging from any particular point, shall be brought to a focus and form an image upon the retina. For the parallel rays proceeding from objects at a distance, the static refraction of the eye suffices. From objects closer than twenty feet, the rays are divergent, the amount of the divergence increasing with the nearness of the object, and now the static refraction is insufficient to form a clear image, and the dynamic refraction is brought into play by means of the accommodation, and for each different distance there must be a change in the accommodation, increasing as the object approaches and diminishing as the object recedes.

What is amplitude of accommodation?

This is the power of accommodation which the eye is able to exert and represents the difference in the dioptric power of

the eye when the accommodation is passive and when at its maximum activity, or the difference between the static and the dynamic refraction of the eye. The amplitude of accommodation is greatest in youth and gradually diminishes with age, until at seventy years of age it is entirely lost. About middle life this amplitude is so impaired that near vision is very much interfered with; this condition of presbyopia calls for the assistance of a convex lens to supply the deficiency.

What is convergence? By what means is it obtained?

Convergence is the act of directing the visual axes of the two eyes to the same point at some near distance, in order that the images formed in the eyes shall be caused to fall on the macula of each and be fused so that one object is seen, instead of two. Double vision results when the image falls upon parts of the two retinæ which do not exactly correspond. The nearer an object approaches the eyes, the more strongly they must be converged, while at great distances the need of convergence diminishes correspondingly.

The function of convergence is accomplished by means of the internal recti muscles, which are also known as the muscles of convergence.

What constitutes the amplitude of convergence?

The amplitude of convergence is the power of convergence, or the whole amount that can be produced by the strongest effort of the internal recti muscles, and it is usually expressed in meter angles. At extreme distances the visual lines are assumed to be parallel; when the eyes are directed to an object one meter away, the visual lines must converge to this point, thus forming the meter angle, which in this case, equals one and may be expressed as follows: $C = 1$ (the C being the sign for amplitude of convergence.)

If the object looked at be situated at half a meter, the angle will be twice as great, and then $C = 2$. If situated at one-third of a meter, the angle of convergence is correspondingly increased, and then $C = 3$. If the object is removed two meters or four meters, the angle is diminished in proportion, and then $C = 1/2$ or $C = 1/4$.

What is the visual field? The visual line?

The visual field is the circular space in front of each eye, within which objects are distinctly perceptible while the eye is in a fixed position. In some of the lower animals, on account of the position of the eyes, the field of vision is a complete sphere, objects being visible in every direction. In man the field is limited, and yet it amounts to almost 180° because if the object is brilliant and placed laterally at the external borders of the field, it does not escape perception.

Within this field, however, there is only one point where objects can be seen with perfect distinctness, and that is in the center of the field, and its prolongation forward from the pupil is known as the "line of direct vision."

The limitation of distinct sight to the line of direct vision is practically compensated for by the great mobility of the eyeball, which rapidly turns in all directions, shifting the line of vision and examining, in turn, every part of the field of vision.

What is meant by binocular vision?

When the two eyes are directed to an object, an image is formed in each and the function of convergence which presides over this department of vision so directs the visual axes of the two eyes that the image is formed on the macula of each eye or, at least, on "corresponding portions" of each retina. The impression is carried to the brain by each optic nerve, but as the images are exactly alike and are formed on parts of the two retinæ that correspond, they are so combined by the brain as to give the impression of a single object. This simultaneous use of both eyes, resulting in the production of single vision, is known as binocular vision, which may be briefly defined as single vision with two eyes.

What is the function of the choroid?

The choroid is the vascular coat of the eye and consists of connective tissue stroma which supports the numerous blood-vessels, the larger of which are in the outer layer, while the inner layer is devoted to the capillary network. Therefore, the choroid is to be considered the chief nutritive apparatus of the eye, be-

cause the percipient layers of the retina and the ciliary muscle, which are the most active portions of the organ of vision, receive their nutrition from this source. It also contains pigment matter, which protects the eye from excessive light.

In what way are sight impressions received and conveyed to the brain?

A light wave starts on its journey from the luminous object from which it originates. After undergoing the proper refraction, the first actual step towards becoming a visual impulse is taken when it decomposes the photo-chemical substances of the retina and sets up vibrations in the extreme periphery of the end organs of this membrane.

The excitation received by the retina is then conveyed by fibers of the optic nerve back to centers at the base of the brain and thence to the visual cortex, which is that part of the convoluted cerebral surface concerned with the function of sight. The result in the cortical centers receiving the impulse is a visual sensation or perception.

Why is it necessary for the aqueous humor to be thinner than the vitreous, and yet it has the same density?

These two humors have practically the same index of refraction, viz., 1.33, but they do not have the same consistency, the aqueous being quite thin and watery, while the vitreous is semifluid, gelatinous or jelly-like. One reason why the aqueous should be thinner is that the movements of the iris may quickly take place, with nothing to retard them, as would be the case if the humor in which they floated was thicker.

Why are accommodation and convergence closely related?

The purpose of the latter is to form a clear image upon the retina, while the former directs the two eyes to the same point, so that the image may fall upon the macula of each eye, in order that single binocular vision may result. For every diopter of accommodation there is a corresponding meter angle of convergence for

each eye. In order that this relation may be maintained, nature has very properly provided that the ciliary muscle and the internal recti muscles shall be supplied by the same nerve, the third cranial or oculo-motor nerve. As the years pass the habits formed by the accommodation and convergence become more and more fixed and the relationship made still closer. This association of these two functions is not the same in all people, and as the presbyopic period gradually approaches new relations must be formed.

What influence has the age upon the accommodation?

The accommodation depends principally upon two factors— the contractility of the ciliary muscle and the elasticity of the crystalline lens. As age advances the ciliary muscle gradually loses its power of contractility and the lens its power of elasticity. These two changes, the loss of strength of the muscle, and particularly the increasing hardness of the lens, have necessarily a restricting influence upon the accommodation. The increase in the density of the lens makes it more difficult to be acted upon by the muscle for a change of curvature, even though the latter retained all of its primary strength.

The effect of age upon the accommodation is modified by the condition of the refraction of the eye; in hypermetropia the lessening of accommodative power is intensified and made manifest earlier, whereas in myopia the accommodation is less impaired and, then, not so early in life.

What is the function of the eye-lashes?

When the lids are partly closed the lashes come together in such a way as to form a kind of screen, which, while not excluding vision, serves as a protection against wind and dust and light and all foreign bodies floating in the air.

In what way do they differ from ordinary hairy growths?

Their bulbs are freely supplied with nerves, giving them tactile sensibility, so that they are enabled to act as "feelers" to warn the eye and reflexly cause the lids to close tightly on the

approach of any small object, as an insect in the dark or when the vision is not on guard.

What arrangement is there on the posterior surface of the iris to prevent the transmission of light?

A pigment layer covering the posterior surface of the iris as far as the anterior margin of the pupil.

In what way do the nerve filaments end in the retina?

In the layer of rods and cones.

Which of these is most highly developed in man?

The rods, which are also by far the most numerous.

Which are most numerous of the macula lutea?

The cones; in the fovea centralis they alone are present.

What are entoptic images?

The word "entoptic" is derived from the Greek and means within the eye. These images depend upon the presence of some opacity in the transparent media of the eye, such as muscæ volitantes. They are to be found in all eyes to a certain extent, and are made more evident when looking at a white cloud or any light-colored object, especially through a pin hole.

What is meant by intraocular pressure? √

The tension to which the coats of the eye are put by the varying quantity of the humors of the eye. When the tension is abnormally increased, the condition is known as glaucoma, a disease that is often fatal to vision.

What is the visual purple?

A certain coloring substance of the retina found in the external segments of the rods, the color being uniformly distributed throughout this portion of the rod, while it is absent from the cones and the macula lutea, and hence it cannot be considered essential to the act of vision. But it undergoes changes when exposed to light and, therefore, it is probable that it plays some important role in the visual process. The visual purple disappears when the eye is exposed to light and is restored when the light is excluded. It can be seen by the naked eye or the microscope under the light of a sodium flame in the fresh retinae of animals which have been kept for an hour or two in the dark. When light acts upon the visual purple, it first produces visual yellow and then visual white which latter is described by scientists as a greenish, fluorescent substance.

What relation does the convergence of the eyes bear to the accommodation? Explain fully.

In the normal eye the relation between convergence and accommodation is very close. For every effort of one there is a corresponding effort of the other. In emmetropia at one meter there is required 1 D. of accommodation and 1 meter angle of convergence for each eye; at one-half meter there is required 2 D. of accommodation and 2 meter angles of convergence for each eye and so on.

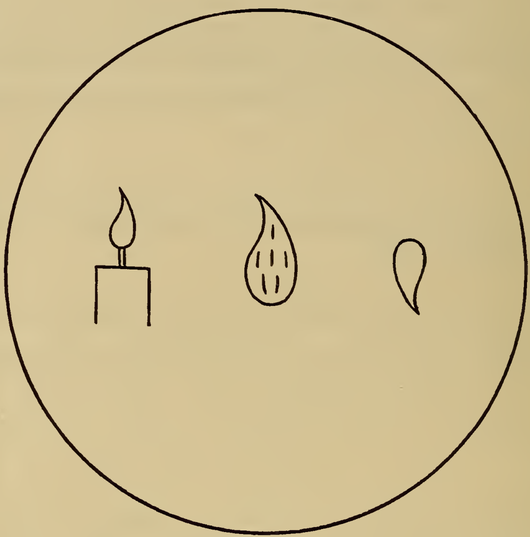
Although so closely associated, the relation between accommodation and convergence is not entirely rigid; within certain limits either may be varied slightly. The accommodation may be lessened by convex lenses or increased by concave lenses, without any change in the convergence. This relative range of accommodation varies in different individuals, from 3 D. in distant vision of a young emmetrope to 6 D. in near vision.

As the accommodation can be thus varied without change of the convergence so the latter within certain limits can be increased or diminished without affecting the accommodation. The convergence can be diminished by a prism, base in, when the accommodation is completely relaxed. It can also be increased by means of prisms, bases out, without bringing the accommodation into action. This relative range of accommodation varies in different persons up to 6 m. a.

The flexibility in the relation between accommodation and convergence is of importance as allowing comfortable binocular vision in ametropia that would otherwise be impossible.

What is the effect of the contraction of the radiating muscles of the iris?

Dilate the pupil.



Candle Flame Images in Eye

FIG. 39

What effect would be produced by cutting (a) the superior oblique muscle, (b) the internal rectus muscle?

(a) The superior oblique muscle turns the eye downward and outward, rotating the upper end of the vertical meridian inward, hence cutting of this muscle would limit the movement downward and outward with a corresponding strabismus upward and inward.

(b) Cutting of the internal rectus muscle would cause limitations of the power of adduction, with perhaps, divergent strabismus and crossed diplopia.

How is the tension of the eyeball regulated?

The tension of the eyeball is maintained by the secretion of the aqueous humor, and its equilibrium is regulated by the escape of this humor into the spaces of Fontana, the canal of Schlemm and the anterior ciliary veins.

What effect would be produced if the sixth nerve were severed?

The sixth cranial nerve is called the abducens and supplies the external rectus muscle of the eyeball. Severence of this nerve would cause inability to turn the ball outwards, with perhaps convergent strabismus and homonymous diplopia, which would be increased by looking toward this side and diminished when looking toward the opposite side.

Why is the optic disk a blind spot in the eye?

It is insensitive to light because the percipient elements of the retina are lacking here.

What is emmetropia and in what way does it differ from ametropia?

Emmetropia signifies an eye in measure, so that parallel rays are exactly focused upon the retina without any effort of accommodation.

This is in contrast with hypermetropia, where the focus of parallel rays is behind the retina and with myopia, where it is in front. In simple astigmatism the focus of one meridian is on the retina and of the other back or in front of it. In compound astigmatism the focus of both meridians is in front or back of the retina, at varying degrees.

What is the range of focus between an eye at rest and one under full accommodative power called?

The range of accommodation.

What is meant by the term visual acuity?

Sharpness of sight or the amount of vision possessed as compared with a standard, and has reference to the ability to perceive and recognize form and outline.

What is anisometropia?

That condition in which the refraction of the two eyes varies.

In high degrees of anisometropia what is the effect of binocular vision?

If the refractive difference is not too great, or if the patient can equalize the refraction of the two eyes by an unequal contraction of the ciliary muscles then binocular vision is likely to be present. But if the difference is considerable and the ciliary muscles receive the same amount of innervation so that the relative difference between the two eyes is constantly maintained the retinal image in the more defective eye is not only dimmer, but of a different size from its fellow under which circumstances the incentive to binocular vision is very much weakened and finally lost, or, if binocular vision is maintained, it is at the expense of constant effort. In other cases of greater inequality of the retinal images, the fusion sense is so weakened that no effort is made to maintain binocular vision. The imperfect image of the poorer eye is ignored or suppressed by the brain, and then monocular vision is said to exist.

What is the yellow spot of the eye?

It is a highly sensitive area of the retina, situated at the back of the eye, in the line of the visual axis about 1.5 mm. to the temporal side of the posterior pole. This area is about 2.5 mm. in diameter, and is also known as the macula lutea, or simply the macula. But the true macula is only about 1 mm. in diameter, and is the area of most distinct vision. In the center of the macula is a minute depression about .25 mm. in diameter, consisting entirely of narrow cones packed closely together, which is called the *fovea centralis* on account of its position, and it is here that vision is most acute.

What is the cause of convergence?

The abhorrence of diplopia or the desire implanted by Nature for single vision and, as a result, the innervation of the internal recti muscles, which are the muscles concerned in the function of convergence.

What is the blind spot of the eye?

It is located at the entrance of the optic nerve, where the fibers pass through the sclerotic at the back of the ball, about 2 mm. to the nasal side of the posterior pole. This optic nerve head, on account of the absence there of the retina proper, is totally insensitive to light, and hence it is known as the blind spot.

We are not conscious of the existence of this blind spot because when our eyes are directed toward an object the image is formed upon the macula, which is in the line of direct vision, while the blind spot is situated to the inner side of this point.

When both eyes are open an object may be so placed that its image falls upon the blind spot of one eye, but in such case it must fall upon the macula of the other eye, and hence the object will be distinctly seen.

It is impossible that an image should fall upon the blind spot of both eyes at the same time.

Even when one eye only is used this blind spot is not noticeable because it is located in a part of the field to which our attention is seldom directed, and where the perception of objects is so imperfect that the absence of one of them momentarily is not regarded.

What is the monocular field of vision?

With the eye looking straight forward (and confined to one eye) it is the space within which objects are visible. Vision is perfect only at the center in the line of direct vision, and becomes less distinct towards the periphery of the field.

Why is binocular field of vision wider than the monocular kind?

Because the second eye gives all the additional field on its side, which is not possible to one eye on account of the projection of the nose.

What is the principal advantage of indirect vision? √

Deprived of indirect vision would place a man in the position of looking through a long, narrow tube, which would allow of seeing nothing but the object in the line of direct vision. It would be impossible to see objects on one side or the other, above or below, without an incessant turning of the head. As a person walks across the street looking straight ahead to the opposite side, where he is going, he is able without turning his head or eyes, to see if any vehicles are approaching in either direction or if there are any obstructions or depressions in the street by means of his indirect vision, the importance of which can hardly be overestimated, as it enables the man to avoid dangers which approach and menace him from all sides.

What causes the crystalline lens of the eye to become more convex when looking at a near object?

The increase in convexity of the crystalline lens is accomplished by means of the contraction of the ciliary muscle.

What is diplopia and how does it differ from heterophoria?

Heterophoria is an imbalance of the ocular muscles; diplopia is double vision. The first is a condition, the second, a symptom. We may have and usually do have heterophoria without diplopia because the eyes are able to overcome the imbalance, but we do not have diplopia without some disturbance of the muscular equilibrium.

Heterophoria must be sought and discovered by the tests of the optometrist, while diplopia is self-evident to the patient himself. Heterophoria may be described as a latent condition while diplopia is always manifest.

What is the difference between binocular vision and fusion?

Binocular vision is single vision with two eyes, and depends upon the blending in the brain of the impressions that are made upon corresponding parts of the two retinae. This usually exists in connection with fusion, as shown in the use of the

stereoscope, where if the pictures are separated or approximated, the eyes will follow them in the interest of binocular vision in the effort to maintain fusion.

It is conceivable that there may be some cases of binocular vision of such grade that the two pictures of the stereoscope will be united in one only when placed in certain relative positions corresponding to the directions independently assumed by the visual axes, showing no effort to produce or maintain fusion on account of an absence of desire for binocular vision.

What is binocular vision?

Single vision with two eyes, for the maintenance of which it is necessary that the images of the object fall upon identical portions of the two retinae in order that they may transmit to the brain a single impression; or the object must be at the point of intersection of the two lines of direct vision.

Vision of one eye gives a flat appearance, while binocular vision gives the impression of depth and solidity, as well as a more correct estimate of distance on account of the amount of convergence that is brought into play.

Describe the mechanism of accommodation.

This depends upon the elasticity of the crystalline lens and the contractility of the ciliary muscle. The latter has such connections with the former that when the muscle contracts the lens becomes more convex, this increase of convexity being greater on its anterior surface, and when the muscle relaxes the lens becomes less convex. There are two theories of accommodation—Helmholtz's and Tscherning's—but the essential feature is that accommodation depends upon an increase in the convexity of the crystalline lens and is accomplished by the contraction of the ciliary muscle.

What is the difference in meaning between amplitude of accommodation and range of accommodation?

The range of accommodation is the distance between the far point and the near point, and is the distance over which the

eye has command by aid of its accommodation. The amplitude of accommodation is the power of accommodation or the force necessary to change the adaptation of the eye from its far point to its near point, and it is represented by the difference in the refractive power of the eye when in a state of complete rest and when at its maximum of accommodation.

What is the function of the cornea?

The function of the cornea is two-fold:

It is part of the external coat, and as it is tough and unyielding, it helps to maintain the shape of the eyeball and protect its contents.

It is also one of the refracting media of the eye, receiving the rays of light, and by its density and convexity converges them towards the next medium.

What is the function of the iris?

To regulate the amount of light admitted to the retina. In a bright light the sphincter fibers contract to protect the eye from the excess of light; in a darkened room the dilator fibers contract to allow the entrance of as much as possible of the insufficient light.

What is the function of the crystalline lens?

To still further converge the rays of light entering the eye, and by its varying convexity to focus them upon the retina no matter what the distance of the object may be from which they come.

What is the result of the functioning of the ciliary muscle?

An increase in the convexity of the crystalline lens as in the act of accommodation, so as to adapt the eye for the diverging rays proceeding from close objects.

What is the purpose of the extrinsic muscles of the eye?

To turn the eyeballs in the various directions that may be necessary and for the maintenance of binocular vision.

What is the difference between supraduction and infraduction?

Supraduction is a turning upward; infraduction a turning downward.

The crystalline lens is sometimes called a humor; is this correct?

The eyeball is described as being composed of three coats within which are contained three humors. These humors are the aqueous, the crystalline and the vitreous. The crystalline is denser and thicker than the other two humors, but at the same time it is jelly-like or semi-fluid, so that it is really a humor.

What is the usual difference between the pupillary distance for far and that for near?

The pupillary distance for reading is about four mm. (one-sixth of an inch) less than for distance.

How can you find the number of degrees of convergence used at the ordinary reading distance?

The degree of convergence is expressed in terms of the meter angle, which is the angle through which each eye must turn from parallelism of the visual lines so that these lines may meet at a distance of one meter. The advantage of this system is that in emmetropia the meter angles of convergence are equal to the diopters of accommodation. The objection to it is that the meter angle has no fixed value on account of the variation in the inter-pupillary distance, but for the average distance it is about 1½°. As the angle of deviation is about one-half the refracting angle of a prism, this would correspond to the deviation of a 3° prism. Therefore, one meter angle of convergence is equivalent to the effect of a prism of 3° before each eye, or to the effect of a prism of 6° before one eye.

At the usual reading distance of 13 inches, where 3 D. of accommodation is in use, the equivalent would be 9° before each eye or 18° before one eye.

Which is the stronger function, accommodation or convergence? On what do you base your conclusion?

There may be a difference of opinion on this point, and it probably varies in different persons and at different times of life. There is always an abhorrence of diplopia, which is more disturbing than a slight indistinctness of vision, and would seem to indicate that convergence was the most important. But, on the other hand, in young hypermetropes in order to bring the accommodation into play and secure clear vision strabismus and monocular vision are established, which would seem to indicate that accommodation was the dominant function.

What are the two associated functions of the eye as regards changes of the gaze from point to point, and what is the nature of this association?

Accommodation and convergence, the association between which being so close that exercise of one of them is involuntarily accompanied by a corresponding action of the other.

What stimulus is it that results in exact binocular vision?

The fusion sense or fusion faculty, aided by a strong natural desire for single vision.

Name all of the extrinsic muscles brought into play in converging to a point eighty inches away; four inches away.

Converging at eighty inches is accomplished mainly by the internal recti muscles. At four inches these muscles are reinforced by the superior and inferior recti muscles.

When is the punctum proximum of accommodation and convergence at the same point?

In emmetropic and orthophoric eyes, when the accommodation and convergence can be used in the same proportion and to the full extent to focus and fix a near object.

In what way does the vision of a color-blind person differ from the vision of a person with normal vision?

Color blindness does not seem to reduce the visual acuity as it might be thought to do at first sight, but as a matter of fact the general vision of the color blind is up to the standard of normal eyes. In those colors which they cannot see as such they can distinguish differences of shade and tone that are dependent upon the admixture of white, even better than normal eyes.

When a totally color blind person looks at a colored object he is conscious only of the white light which is present in varying degrees in every color, and instead of color the object presents shades of gray, as in an engraving. In cases of blindness for red, when a red object is looked at there is no stimulation of the red fibers, but there is an impression of the green fibers, and to a slight extent of the violet. A red object therefore makes the same impression as a green one, but he is sometimes able to distinguish between the two by their difference in brilliancy.

Why are we not conscious of the existence of the blind spot when we close one eye?

Because it covers such a small area, and besides is located in a part of the field of vision to which our attention is scarcely directed, and where the perception of various objects is so imperfect that the momentary absence of one of them is not regarded; and finally because the brain from long experience has learned to ignore it.

What is the purpose of the iris of the eye and to what extent is it effective?

To regulate the amount of light admitted to the eye. There is a limit to its contractibility in shutting out excessive light, as there is to its dilatability in admitting diminished light.

What is the difference in the dioptric power of the eye between when the accommodation is at rest and in full force called?

It is that which is supplied by the amplitude of accommodation, which, added to the power of refraction of the eye when in repose, represents its full positive refracting power.

What effect does age have on the accommodation and on the convergence?

There is a steady and gradual diminution of the power of accommodation with the advance of years, while the power of convergence is but little if any affected.

What is meant by positive and negative convergence, and what is the total amplitude of convergence?

Positive convergence is the turning inward of the visual lines so that they shall meet at the point of fixation.

Negative convergence is a divergence of the visual lines.

The total amplitude of convergence is represented by the nearest point for which the eyes can converge. If this point was 5 inches, it would represent a converging power of about 8 meter-angles.

What is meant by the term binocular vision?

Single vision with two eyes.

In what way does the human eye resemble a photographic camera and in what way is it different?

In the human eye the image is formed on the retina by means of the crystalline lens which is adjustable for vision at different distances, very much as in the camera, the image is formed on the sensitive plate or film by means of the converging lens, the instrument being adjustable for objects at different distances, by altering the distance between the lens and the film, which is capable of receiving only one image, while the capacity of the retina is unlimited.

Why does the pupil of the eye look black when it is really transparent?

Because there is no intraocular illumination, or no inside light to come out. If light entered the eye from a flame, it would return in the same direction from which it came, and in order for the observer to see it, he must get in the path of the returning rays, and in so doing his head gets in the way and shuts off the entering light. This is overcome in the ophthalmoscope where the mirror acts as the source of light, and in returning some of the light passes through the sight hole into the eye of the observer.

What is the difference between monocular vision, binocular vision and the fusion sense?

Monocular vision is one eye vision. In binocular vision both eyes are used and the image formed on the macula of each, but they are blended in the brain so that we are conscious of only one object.

The fusion sense may be regarded as presiding over binocular vision, and is that function of the visual centers in the brain that enables fusion of the two images to be made and maintained.

How is the accommodation of the eye produced and why does it fall off with age?

The accommodation is produced by an increased convexity of the crystalline lens and is caused by contraction of the ciliary muscle. It lessens with age because the crystalline grows denser and harder and is not able to respond so readily to the action of the ciliary muscle.

What is the range of accommodation in any individual, and how may it be measured?

The writer regards the distance between the near and the far points over which the eye has command, by the aid of its accommodation, as the range of accommodation.

But the question implies what the writer terms the amplitude of accommodation, which is the force necessary to change the eye in its adaptation from its far point to its near point and is represented by that convex lens which would enable the eye

to see at its near point when the accommodation is at rest. The accommodation is therefore equal to a convex lens if such strength as will give to rays proceeding from its near point the same direction as if they come from the far point. Hence we measure the near point and transpose into D's. As for instance a near point if ten inches represents an accommodation of 4 D.

What is meant by the term spasm or cramp of the accommodation?

A persistent contraction of the ciliary muscle, which fails to relax, even when there is no need for its contraction.

What is the difference between subnormal accommodation and subnormal range of accommodation?

By subnormal accommodation the writer would understand that the power or amplitude of accommodation was below the normal standard for that particular age.

By subnormal range of accommodation we would understand that the distance between near and far points is less than normal.

How close is the relation between accommodation and convergence?

This relation is close but not absolute, because although so intimately connected, they may within certain limits be used independently of each other.

For instance, the effort of accommodation may be increased or diminished by the use of concave or convex spheres, respectively, while the same degree of convergence is maintained.

Or the effort of convergence is lessened by prisms bases in without a corresponding diminution of accommodation, as shown by the fact that the distinctness of the object is not impaired.

Or the effort of convergence may be increased by prisms bases out without a corresponding increase of accommodation, as shown by no interference with the clearness of vision.

But at the same time the general statement holds good that the functions are so closely related that with every effort of accommodation there is a corresponding effort of convergence.

Why is it that while the orbits diverge the eyes look straight ahead?

By the action of the extra ocular muscles, and especially the internal recti. These are the strongest of all the muscles and easily overcome the divergence of the orbits.

When is an eye orthophoric?

When there is no imbalance of the extra ocular muscles.

What is meant by acuity of vision and what is the usual standard of the same?

Acuteness of vision is a function of the nervous system of the eye; it is for the retina what tactile sensibility is for the skin, and the two functions are determined in a similar manner. We seek in both for the smallest distance between two points which can be perceived separately. For the skin, the mechanical pressure of two points of a compass is employed; while for the retina it depends upon the retinal images of two luminous points.

Visual acuity therefore represents the smallest retinal image, the form of which can be distinguished, for which its two points must be separated by a certain small distance, and this distance corresponds in the normal eye to a visual angle of one minute.

Why does not the amplitude of the convergence fall off as rapidly with age as does the amplitude of the accommodation?

It is probable that all the muscles of the body show some loss of power with the advance of age, but the more rapid loss of accommodation is due rather to the increasing firmness of the crystalline lens than to the loss of power of the ciliary muscle, and as a result the former does not respond to the latter. It is fair to conclude that the ciliary muscle does not weaken any faster than the muscles of convergence, but the first is no longer able to increase the convexity of a crystalline which has become dense and hard, whereas the second simply causes motion and there is no change occurring in the eye to make that motion more difficult.

What is meant by the term "axis of the eye," and has the human eye an axis?

The human eye anatomically speaking does not have an axis, but the term "axis of the eye" is an imaginary line which passes perpendicularly through the center of the cornea, the center of the crystalline lens and the center of the fundus, which latter is a little to the nasal side of the macula lutea. The front end of this line at the apex of the cornea is the *anterior pole*, and the other end at the center of the fundus is the *posterior pole.*

What is abduction of the eyes and when is it exerted and by what muscles?

Abduction is turning of the eyes outwards, and takes place when looking out at distant objects after the eyes have been converged in near vision and is effected by the external recti muscles. It may be considered a passive function, in contrast with adduction which is an active one.

When prisms are placed before the eyes bases in abduction is called into action to prevent diplopia.

How can one see opacities in his own eyes if any be present?

Any object in the eye in front of the sensitive retina intercepts the light that passes through the pupil and throws shadows which, under certain conditions, can be perceived. A flame at a distance of fifteen feet is looked at through a strong convex lens held two or three inches from the eye, when a bright patch of light will be seen formed by circles of diffusion, upon which the presence of any opacities in the eye becomes manifest by the shadows that are thrown upon it.

What is the difference between the optical and visual axis of the eye?

The optic axis is an imaginary line that passes perpendicularly through the center of the cornea, the center of the crystalline lens and the center of the fundus, which point is usually near the inner margin of the macula.

The visual axis is an imaginary line that passes from the object looked at through the nodal point to the macula.

It is possible that the visual axis should coincide with the optic axis, but it seldom does; the two axes crossing and forming at the nodal point of the angle of Alpha or of Gamma.

What advantage has binocular vision over the monocular form, as possessed, for instance, by a one-eyed man?

The advantages of binocular vision are the power to recognize depth and perspective or the appreciation of solidity; and the more correct estimation of distance as indicated by the amount of convergence necessary.

What is the blind spot and why is it so called? How may its location be detected?

The blind spot is at the entrance of the optic nerve, and it is so called because of the absence of the percipient layer of the retina there. It is insensitive to light.

It can be detected by the following experiment: two black spots on a white card, left eye closed and with right eye look at left hand spot. The card is moved farther from or closer to the eye until a position is found where the right hand image is lost, because its image falls upon the blind spot. As the position of the card is varied, the spot again comes into view.

Why is the association of accommodation and convergence a close one?

Because it is necessary to use both in equal proportion in near vision, and because Nature made it so, both functions being supplied by the third cranial nerve.

Why does the pupil look black when it is really transparent?

Because of the absence of intra-ocular illumination, and because there are no rays of light passing from the eye of the patient to the eye of the observer. Rays of light entering an eye

are reflected back to their source, and in order to obtain an illuminated pupil these returning rays must be intercepted.

This is accomplished by making a mirror the source of light, and as the rays from the observed eye return to the mirror, the observer is able to receive some of these return rays through the opening in the mirror.

What is the result of contraction of the radiating muscular fibers of the iris?

Dilatation of the pupil.

Pathological Conditions

What are the different forms of color blindness?

The different forms of color blindness are red, green and violet, of which the first two are the most common.

How can we tell whether there is any sense of light in a suspected case of cataract?

By means of a lighted candle in a darkened room, and by the ability of the patient to recognize the light and locate the direction from which it comes.

How can you tell if a patient has glaucoma or not? What do you see with the ophthalmoscope that will give you this information?

By the rapid recession of the near point, by the increased tension and stony hardness of the eyeball, by the subjective symptom of halo or rainbow around a light, by severe neuralgic pains that are complained of, by sluggish or immobile pupil, by impairment of vision, by cloudiness of the aqueous and vitreous and cornea, and by contraction of the field of vision. The ophthalmoscope will show venous congestion, arterial pulsation and cupping of the optic disk.

What is the difference between an amblyopic eye and an asthenopic eye?

In the amblyopic eye vision is impaired and no improvement is afforded by glasses. In the asthenopic eye, vision is usually good, but the eyes can be employed but little for close work, because all such use of the eye is attended with discomfort or pain. An amblyopic eye has blurred vision, while an asthenopic eye means weak sight.

What is meant by retinal fatigue, and how is its existence generally proved?

This means exhaustion of the optic nerve and retina, and quickly comes on when the eyes are steadily fixed on one object, and manifests itself by impairment of vision.

This is brought home to the optometrist in his daily work. The patient is looking intently at the test letters as one lens after another is tried; he is unable to decide which lens is the better, in fact he will probably say he cannot see the letters at all. A closing of the eye or turning in another direction suffices to relieve the exhaustion of the retina and allows the examination to proceed. The optometrist would do well to take advantage of these rests frequently during his examination.

What is the effect on the mobility of the eye if the internal rectus is paralyzed?

Partial or total loss of power to turn eye inward, thus impairing the function of convergence.

Suppose an accident happens to the eye whereby some of the aqueous humor and some of the vitreous humor is lost. Will nature replace these humors?

The aqueous humor will be quickly replaced, but the vitreous never.

In color blindness of the usual type, why does the patient confuse shades of green with shades of red?

According to the Young-Helmholtz theory we have three primary color perceptions corresponding to the three primary colors of red, green and violet. The absence or impairment of one or more of the primary perceptions constitutes color blindness, as a result of which these colors are confused. These color sensations are conveyed to the brain by three sets of nerves, each set conveying not only the sensation of its special color, but also to a slight extent that of the other two.

In color blindness there is a loss of sensation to one or more of the three colors, or an impairment of one or more of the sets of nerves, which is discovered when the patient is asked to match various colored skeins of yarns.

What explanation can be given for the oscillation of the eyes in many albinos?

This condition, to which the term nystagmus has been given, is most commonly found in persons with congenitally defective vision, among whom albinos are to be classed. On account of the lack of pigment in the choroid and iris, there is no provision for modifying the brightness of the light, and the patient suffers from the dazzling, and his vision is impaired. Just how the oscillation is produced is a disputed question, but it is probable that in these congenital cases the absence of the stimulus which distinct retinal images cause, interferes with the development and functioning of the centers in the brain that govern the co-ordination of the ocular muscles.

It is an interesting fact that in those patients where the nystagmus is due to a congenital defect, there is no complaint of oscillation of objects looked at; whereas, when the affection comes on later in life, such patients are very much annoyed by this symptom.

What is amblyopia and what are some of the causes of it?

Amblyopia is impaired vision, which is not caused by an error of refraction, but is due to functional disturbance or disease of some part of the visual apparatus, either the retina, the optic nerve or the brain. It sometimes exists without any evidences that are visible to the ophthalmoscope.

Amblyopia *ex anopsia* is due to non-use of one eye as in strabismus. Reflex amblyopia to irritations in some other part of the body. Traumatic amblyopia to injury. Uræmic amblyopia to Bright's disease. Toxic amblyopia to tobacco and alcohol in excess.

It may be recognized by its inability to respond to any glass placed before the eye, and by the failure of the pin hole to afford any improvement in vision.

Why is it, after the removal of a cataract, that a strong glass can be placed over the aphakic eye and be worn with comfort, when this cannot be done in cases of high anisometropia?

This is possible only when the other eye suffers with impaired vision, probably from a partly developed cataract. Under such conditions the burden of vision is borne by the aphakial eye with its proper correction. As long as the vision of one eye is good, or at least serviceable, it is not customary to perform a cataract operation on the other eye, but a time finally comes when vision has been so much impaired that something must be done, and then the poorest eye is operated upon. If successful the vision of this eye with its correcting lens is so much better than the other eye, that it becomes the dominant eye, and is not disturbed by the relatively poorer vision of the other eye.

When is detachment of the retina to be suspected?

The diagnosis of this condition can be made only by the ophthalmoscope. In a partial detachment the normal reflex is absent at the portion detached, and instead it is grayish or whitish on account of opacity of the retina. As the detached portion projects into the cavity of the eyeball, it can be examined by the direct method with a convex lens. The gray reflection can be seen to be folded, and the few retinal vessels that pass over it have lost their light streak, appear dark in color and pursue a tortuous course. When the eye is quickly moved in different directions, motion can be observed in the folds depending upon the amount of the underlying fluid.

What is the effect of atropine?

To suspend accommodation and dilate the pupil. It paralyzes the peripheral cells of the third cranial nerve as supplied to the ciliary muscle and the iris, while it stimulates the radiating muscular and sympathetic fibers of the iris.

What is meant by night blindness?

This is a well recognized symptom of the disease known as retinitis pigmentosa. While vision is never perfect, yet such a patient can see fairly well in bright daylight, but on a dull day or at twilight or by insufficient artificial light, vision is very

greatly impaired. This is said to be due to defective power of adaptation of the retina, rather than to defective light sense.

What is cataract and what is the popular conception of it?

Cataract is a translucent or opaque crystalline lens. It is sometimes spoken of as "on the eye," when it is confused with an opacity of the cornea.

Why may a chalazion temporarily change the refractive condition of the eye?

This is a small tumor of the lid and it is possible that by pressure on the cornea it may so change its curvature as to produce a temporary condition of astigmatism.

Is there a difference between color blindness and color ignorance?

Color blindness is a congenital condition, and is due to the absence or deficiency of one of the retinal color elements; while, in color ignorance there is an inability to name colors because of lack of training or education in them.